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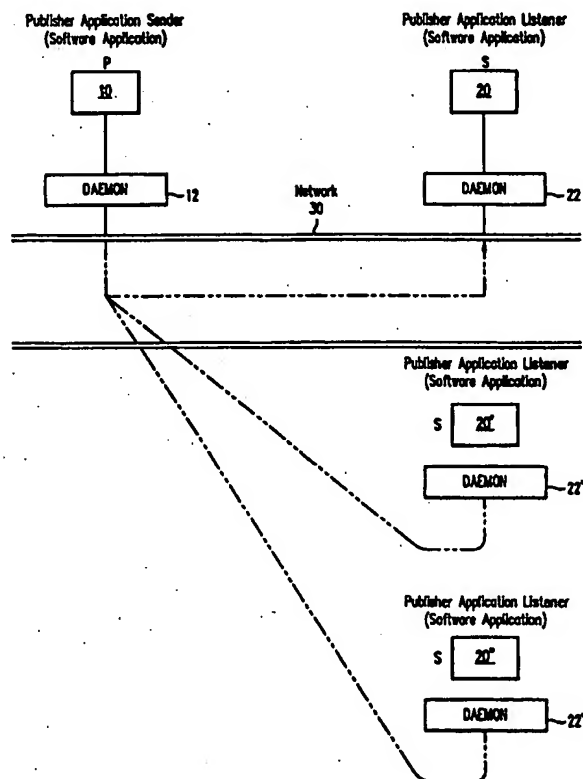
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(54) Title: **CERTIFIED MESSAGE DELIVERY AND QUEUING IN MULTIPOINT PUBLISH/SUBSCRIBE COMMUNICATIONS**

(57) Abstract

A method for certified delivery of an outgoing message or messages in a multipoint anonymous, publish/subscribe telecommunications system. The system for utilizing the method and program product is one having at least one publisher (10) and at least one subscriber (20). The method is carried out by first establishing a certified delivery session ledger. Next each outgoing message is labeled with a label including the delivery session name and a sequence number. The labeled outgoing message or messages are then sent to subscribers, and received by a subscriber. Various protocols are described.



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**CERTIFIED MESSAGE DELIVERY AND QUEUING IN MULTIPOINT  
PUBLISH/SUBSCRIBE COMMUNICATIONS**

**BACKGROUND TO THE INVENTION**

5

**Technical Field**

This invention relates to multipoint publish/subscribe communications and, more particularly, to certified message delivery and queuing between multipoint computer-based publisher and subscriber applications.

10

**Background**

In a typical anonymous public/subscribe technologies -- such as described in US patents 5,557,798; 5,339,392; 5,257,369 and 5,187,787 -- a publisher application publishes information to requesting or subscriber applications without having any knowledge of the number, identity or address of any such subscriber applications. In fact, no subscriber applications may exist. Instead of knowing about subscribers, a publisher will merely publish information applying a context or subject "label" to the published message. A subscriber then identifies desired messages by the content label and receives only those messages relevant to the desired content.

20

The advantages of such a publish/subscribe, content-based addressing systems are well known and include the ability to decouple subscribers and publishers from one another. This decoupling allows publishers and subscribers to operate without having any knowledge of the identity, location or address, or communication protocols of each other. The flexibility that this offers is enormous and, accordingly, such content/subject-based addressing communication-environments are becoming increasingly popular.

Unfortunately, the very advantages (such as anonymous decoupling) of these systems, precludes the use of conventional reliable messaging protocols such as TCP. TCP, and other reliable messaging protocols apply only in point-to-point type of communications. In these point-to-point communications message senders and

30

receivers are directly linked to one another and therefore know each other's addresses and locations.

5 Unfortunately, these reliable messaging protocols -- that guarantee arrival and order of arrival of messages -- require advance knowledge between applications. They are, therefore, not applicable to typical publish/subscribe environments.

10 Yet, such reliable or certified delivery of messages is extremely important. For example, certified delivery is appropriate when a sending application requires individual confirmation of delivery for each message it sends. For example, a travelling sales representative computes sales figures on a lap-top computer, and sends them to a supervisor at the office. The user must know for certain that the data has arrived, and has been included in the supervisor's sales report.

15 Certified delivery is also appropriate when a receiving application cannot afford to miss any messages. For example, in an application that processes orders to buy and sell inventory items, each order is important. If any orders are omitted, then inventory records are incorrect.

20 In addition, certified delivery is appropriate when each message on a specific subject builds upon information in the previous message with that subject. For example, a sending program updates a receiving database, contributing part of the data in a record, but leaving other parts of the data unchanged. The database is correct only if all updates arrive in the order they are sent.

25 Furthermore, certified delivery is appropriate in situations of intermittent physical connectivity--such as discontinuous network connections, for example, an application in which several mobile lap-top computers must communicate with one another. Connectivity between mobile units is sporadic, requiring persistent storage of messages  
30 until the appropriate connections are reestablished.

Thus, a very real need exists for having both the advantages of certified messaging and the advantages of content-based, anonymous publish/subscribe environments.



### SUMMARY OF THE INVENTION

Briefly, according to this invention a publisher publishes a message to any number of unknown subscribers. Note, as used herein "publisher" and "sender" are used synonymously, and "subscriber" and "listener" are used synonymously. The message is published indicating the subject or content using typical content-based publish/subscribe protocols. Subscribers interested in receiving information on the designated content receive the message without knowing about the publisher. Thus the publisher information remains transparent to the subscriber.

In circumstances where the certified messaging is required, the invention provides for establishing a message delivery tracking session. This session includes a name and a ledger used for tracking.

Using these functions the system can track delivery of messages and notify publishers/senders if messages are not delivered. In one embodiment of the invention, delivery attempts are repeated for a preset time (or number of delivery attempts) to ensure or attempt to ensure delivery.

This invention also extends to queuing messages for certified delivery. This occurs when certified delivery is required for a one of a group of  $n$  possible recipients. The system ensures that one (and not all) of the group receives the message. This is accomplished by having members of the group indicate their availability or capacity and having the system route the message to the subscriber (listener) with the greatest availability.

An extension of this concept is the scheduling of tasks for a group of  $n$  possible task performers, each available to accomplish a task. Each task doer, notifies the system of its availability/ability to accomplish tasks. Tasks are then sent to/queued for each task doer according to a rating based on its availability.

### Advantages of the Invention

This invention has a number of advantages. For example, it provides:

#### Certainty

Certified delivery assures application programs that every message reaches each

intended recipient--in the order sent. When delivery is not possible, both senders and, optionally, listeners receive explicit information about each undelivered message.

#### Convenience

5 Once a program sends a certified message, the system continues delivery attempts until delivery succeeds, or until the message's time limit expires.

#### Control

Application programs determine an explicit time limit for each message.

10 Sending applications can disallow certified delivery to specific listening sessions.

#### Detail

The system can also present advisory messages to inform application programs of every significant event relating to delivery.

#### Process-Based or File-Based Recording

15 The system can also record the status of each message in a ledger. Applications that require certification only for the duration of the application process can choose a process-based ledger. Applications that require certification that  
20 transcends process termination and restart can choose a file-based ledger.

The invention will be described in greater detail below with reference to the accompanying drawings.

### 25 DESCRIPTION OF THE DRAWINGS

In the attached drawings:

Figure 1 is a schematic representation of a typical publish/subscribe environment useful for illustrating this invention; and

30 Figure 2 is a schematic representation of a typical publish/subscribe environment useful in illustrating the distributed queuing and task scheduling aspects of the invention.

### SPECIFIC DESCRIPTION

**OVERVIEW**

Figure 1 shows a publisher application (sender) 10 and a plurality of subscriber applications (listeners) 20, 20' and 20". In the preferred embodiment of this invention the publisher and subscriber(s) are software applications based on one or more  
5 computers interconnected by a network 30 providing a data path among the applications. The publisher 10 and subscriber(s) 20 preferably implement a content-based communications protocol whereby a publisher publishes a message indicating only the content of the message and without knowing the identity or protocols used by the subscriber(s) 20. These inter-application communications are established by  
10 communications daemons 12 (associated with a publisher/sender) and 22, 22' and 22" (associated with the subscriber/listener 20, 20' and 20"). The arrangement shown in this figure is well known and described in many publications including the patents referred to above.

15 As is described in much greater detail below, a listener 20 can register with a specific publisher 10 to receive certified messages. This communication includes the subscribers name, its "inbox" address and the subject/content of messages it requires information on. Thus the publisher 10 will have a list of subscriber names and inboxes (but know nothing else about the subscriber) for all subscribers wishing to receive  
20 certified messages. The publisher/sender 10 will therefore expect an acknowledgement of each message it sends out; an acknowledgement it would receive from a subscriber/listener 20, 20' and/or 20". Importantly, if the publisher/sender 10 does not receive the acknowledgement, it sends an acknowledgement request message, usually for a predetermined time or number of "sends."

25

In the event the subscriber wishes to have guaranteed delivery of messages, the publisher can save the message to disk (or other storage) until an acknowledgement of subscriber receipt occurs. Thus, until message times out, the subscriber can, at a later date, receive the message by contacting the publisher. This would usually happen  
30 where messages are very dependent on their sequence or build upon prior message. In these circumstances missing/unreceived messages could be catastrophic. Also, in these (and in most certified messaging applications of this invention) each certified message is assigned a tracking number. This allows both sender and listener/subscriber to monitor which messages are received and/or missing.

In many applications, data communications are highly reliable, but in some situations applications require even stronger assurances of delivery. Certified delivery features offers greater certainty of delivery even in situations where processes and their network connections are unstable.

5

### ***CERTIFIED MESSAGING***

#### **Enabling a Delivery-Tracking Session**

The first step toward certified delivery is to enable a delivery-tracking session. A  
10 delivery-tracking session begins as an ordinary anonymous publish/subscribe session; enabling a session adds information so that it can participate in certified delivery protocols. The additional information includes a name and a ledger.

Delivery-tracking sessions can send and receive messages, just as ordinary sessions  
15 can. In addition, delivery-tracking sessions can participate in certified delivery calls (that is, calls in the rvcn library layer); ordinary sessions cannot participate in these calls. (Notice the asymmetry. Delivery-tracking sessions can participate in ordinary calls, but ordinary sessions cannot participate in certified delivery calls.)

#### **20 *Name***

Each delivery-tracking session has a name which may be reusable, or non-reusable. The name identifies the session to other delivery-tracking sessions, and is part of the label that identifies outbound messages from the session.

25 A name is reusable when a program supplies it explicitly to the enabling call. When a session with a reusable name also has a file-based ledger, it operates as an instance of a persistent correspondent--which allows continuity of certified delivery beyond session termination and program restarts.

30 Two delivery-tracking sessions must not bind the same reusable name that is, at any moment in time, each reusable name must be unique. Sessions may reuse a name sequentially, but not simultaneously. Violating this rule can significantly obstruct certified delivery. Typically, session names have the same syntax as subject names.

Programs may omit a name in the enabling call--in which case the call generates a unique, non-reusable name for the session. No other session on any computer can ever have the same name. As a result, a session with a non-reusable name operates as a transient correspondent--no subsequent session can continue the certified delivery behavior of the session.

Enabling a delivery-tracking session creates a ledger for it. Certified delivery software uses the ledger to record information about every unresolved outbound certified message, every subject for which this session receives (inbound) certified messages, and other cooperating delivery-tracking sessions.

Programs may store the ledger in a ledger file, or in process-based storage within the running program. (Even when a session uses a ledger file, it may sometimes replicate parts of the ledger in process-based storage for efficiency; however, programmers cannot rely on this replication.)

Ledger files must be unique. That is, two sessions must not use the same ledger file (concurrently). If an operating system supports raw disk devices (also called raw partitions), a device can be specified as the ledger file.

A session with a file-based ledger and a reusable name qualifies as a persistent correspondent, with certified delivery behavior that can extend beyond session termination.

## **25 Labeled Messages**

A labeled message is like an ordinary message, except that it includes supplementary information, which delivery-tracking sessions can use for certified message delivery:

30       The name of the delivery-tracking session that sent the message.

      A sequence number assigned by the sending session.

### ***Sending a Labeled Message***

Any delivery-tracking session can send a labeled message by using the sending calls in the certified message delivery library layer. Examples of such delivery-Tracking Send Calls are in the table below.

C	<code>rvcm_Send ()</code> , <code>rvcm_SendWithReply ()</code>
C++	<code>RvCmSender::certifiedSend ()</code> ,
	<code>RvCmSender::certifiedSendRequest ()</code>
Java	<code>RvCmSender.certifiedSend ()</code> ,
	<code>RvCmSender.certifiedSendRequest ()</code>

5

### Receiving a Labeled Message

For clarity, two kinds of listening endpoints are distinguished. An ordinary listener is a listener created with an ordinary listening call, such as the C functions `rv_ListenInbox ()` or `rv_ListenSubject ()`. A delivery-tracking listener is a listener created with a delivery-tracking listening call, such as the C functions `rvcm_ListenInbox ()` or `rvcm_ListenSubject ()`.

10

Either type of listening endpoint can receive a labeled message—delivery-tracking listeners (created by the certified delivery library), as well as ordinary listeners.

15

When an ordinary listener receives a labeled message, it presents it to the appropriate callback function as if it were an ordinary message. That is, it ignores the supplementary information that distinguishes a labeled message.

20

When a delivery-tracking listener receives a labeled message, its behavior depends on context:

If a delivery-tracking listener is registered for certified delivery, it presents the supplementary information to the callback function.

25

If a delivery-tracking listener is not registered for certified delivery, it presents a “null”

sender’s name to the callback function, with a sequence number of zero.

In addition, if appropriate, the certified delivery library automatically requests that

the sender register the listener for certified delivery.

5

## DISCOVERY AND REGISTRATION FOR CERTIFIED DELIVERY

### *Discovery*

When a delivery-tracking listener receives a labeled message from a delivery-tracking sender that is not listed in the listener's ledger, the listener "discovers" the sender on the message subject.

10

Three events follow discovery:

15

Certified delivery software adds the sender's name to the listener's ledger, as a source of messages on the subject.

20

Certified delivery software in the listening program contacts the sending program to request registration for certified delivery of the subject and information regarding the agreement.

Certified delivery software presents a REGISTRATION. DISCOVERY advisory to the listening program.

25

### *Registration*

When a delivery-tracking sender receives a registration request from a delivery-tracking listener, the sender automatically accepts the request. Acceptance consists of these four events:

30

Certified delivery software registers the listener for certified delivery of the subject--recording that fact in the sender's ledger.

Certified delivery software in the sending program notifies the listener session that the registration requested is accepted--the sender accepts responsibility for certified delivery on the subject.

5 Certified delivery software presents a REGISTRATION. REQUEST advisory to the sender session, informing it of the new registered listener.

When the certified delivery software in the listening program receives the acceptance reply, it presents a REGISTRATION CERTIFIED advisory to the listener session.

10

#### **CERTIFIED DELIVERY AGREEMENT**

Following registration and acceptance, the sender and listener have a certified delivery agreement on the subject.

15

The sender is responsible to record each outbound message on that subject, and to retain the message in its ledger until it receives confirmation of delivery from the listener (or until the time limit of the message expires).

20

In return, the listener is responsible to confirm delivery of each message, and to request retransmission when a message arrives out of sequence.

The system arranges all of this accounting automatically. The sending and listening programs do not participate directly in these protocols--only indirectly, by sending and listening with certified delivery library calls.

25

Notice that a certified delivery agreement applies in one direction only--from a sender to a listener. A two-way conversation requires two separate certified delivery agreements.

30

We refer to the two participants in a certified delivery agreement as a certified sender and a certified listener, and the labeled messages that flow between them are certified messages. Notice the subtle difference in terminology--before establishing a certified



delivery agreement, the participants are delivery-tracking senders and listeners; afterward, they are certified senders and listeners. A labeled message is only a certified message when the sender and receiver maintain a certified delivery agreement.

## 5 DELIVERING A CERTIFIED MESSAGE

Once a delivery agreement is in place, all subsequent messages on the subject (from the certified sender to the certified listener) are certified messages. Each certified message generates a series of protocol events:

10 When the system presents a certified message to the listening callback function, it includes the sequence number assigned (automatically) by the sending Software and the publisher's name.

15 When the callback function returns, certified delivery software automatically confirms delivery to the sender and records confirmation to a ledger. (Programs can override this behavior and confirm delivery explicitly.)

20 When confirmation reaches the sending program, certified delivery software records delivery in the sender's ledger, and presents a DELIVERY.CONFIRM advisory to the sender session.

25 When confirmation has arrived from every certified listener for this message, certified delivery software deletes the message from the sender's ledger, and presents a DELIVERY.COMPLETE advisory to the sender session.

### Automatic Confirmation of Delivery

The default behavior of certified listeners is to automatically confirm message delivery upon return from the data callback function. Programs can selectively override this behavior for specific listening endpoints (without affecting other listening endpoints).

30 By overriding automatic confirmation, the listener assumes responsibility for explicitly confirming each inbound certified message.

Consider overriding automatic confirmation when processing inbound messages involves asynchronous activity, such as computations in other threads, database queries, or additional network communications.

**5     *Requesting Confirmation***

If a certified sender does not receive prompt confirmation of delivery from a certified listener (for example, because of network glitches), the system in the sending program automatically requests confirmation. After each request, it presents a DELIVERY.NO\_RESPONSE advisory to the sending session.

10

When a listener receives a request for confirmation, it checks its ledger, and reconfirms receipt of the messages that it has already confirmed. (This behavior is identical, whether the program uses automatic confirmation, or overrides it.)

**15     SEQUENCING AND RETRANSMISSION**

A delivery-tracking sender assigns sequence numbers serially for each outbound subject, so the sequence numbers reflect the order of messages from a sender on a specific subject.

20     When certified delivery software presents certified messages to a certified listener, it preserves the sequence in which the sender sent them. If a message arrives out of sequence, certified delivery software in the listener does not present it to the callback function until all the preceding messages are available.

25     For example, a certified listener is receiving certified delivery for the subject FOO from a sender named BAZ. After receiving and presenting message number 32, the next message to arrive is message 35. Certified delivery software holds message 35 until it can first present messages 33 and 34.

30     Meanwhile, the certified delivery software in FOO requests retransmission of messages 33 and 34 from Baz. In a case where the time limit on those messages has expired--so BAZ no longer has them in its ledger--certified delivery software presents a DELIVERY.UNAVAILABLE advisory to the listener, indicating that messages 33 and 34 are no longer available. Then it presents message 35 to the data callback function.

**PERSISTENT CORRESPONDENTS**

We introduced the concept of persistent correspondents in the section Name, page 144.

- 5 A reusable name and a file-based ledger allow a persistent correspondent to continue certified delivery beyond the termination and restart of a session or process.

***Example***

- 10 Consider an example application system, in which application program JOE generates important information, and sends it to application program SUE in certified messages on the subject REMEMBER.THIS. Upon receipt, SUE stores the information in a database.

- 15 If either JOE or SUE terminate unexpectedly, it is crucial that certified messages still arrive for entry into the database. To ensure this result, both programs must represent persistent correspondents-that is, both programs enable sessions with reusable names (JOE\_PC and SUE\_PC), and each program keeps a file-based ledger. In addition, SUE requires old messages when it enables the session SUE\_PC.

- 20 During operation, JOE has sent message number 57 on the subject REMEMBER.THIS but has not yet received delivery confirmation for messages 53- 56. SUE is processing message 53, when a sudden hardware failure causes to terminate. Meanwhile, JOE continues to send messages 58-77.

- 25 The computer restarts, and SUE restarts. The ledger file for SUE\_PC indicates that message 52 was received and confirmed for the subject REMEMBER.THIS for a given publisher as JOE\_PC. On restart SUE\_PC will contact JOE\_PC and reestablish their certified delivery agreement. When JOE accepts, JOE\_PC retransmits the stored messages 53-77 on that subject.

- 30 In the above scenario it is important to notice the following:

That SUE does not miss any REMEMBER.THIS messages. However, the new SUE must gracefully fix any difficulties caused by partial processing of message 53 by the old SUE.

JOE and SUE communicate using a broadcast subject name not an inbox. Inbox names are unique, so they cannot continue beyond session termination and restart.

## 5 ANTICIPATING A LISTENER

In some situations, a delivery-tracking sender can anticipate the request for certified delivery from a persistent correspondent that has not yet begun listening.

10 Consider an example in which a database program (DB) records all messages with the subject STORE.THIS. The program DB enables a session that instantiates a persistent correspondent named DB\_PC. All programs that send messages with the subject STORE.THIS depend on this storage mechanism.

15 One such sending program is JAN. Whenever JAN starts, it can anticipate that DB\_PC will request certified delivery of the subject STORE\_THIS. Suppose that JAN starts, but DB is not running, or a network disconnect has isolated JAN from DB. Anticipating that it will eventually receive a registration request for STORE.THIS from DB\_PC, JAN makes an add listener call. The effect is that the software within JAN behaves as if it has a certified delivery agreement with DB\_PC for the subject STORE.THIS. It stores outbound  
20 messages (on that subject) in its ledger. When DB restarts, or the network reconnects, JAN automatically retransmits all the stored messages to DB.

## CANCELLING CERTIFIED DELIVERY

Both listeners and senders can cancel a certified delivery agreement.

25

Listeners cancel by closing the listening endpoint, using calls listed below. Senders with certified delivery agreements to the closed endpoint receive REGISTRATION.CLOSED advisories. HOST.LISTEN.STOP advisories inform other applications of the change.

30 Senders can cancel certified delivery of a specific subject to a specific listener. The sender program deletes from its ledger all information about delivery of the subject to the listener. The sending program receives a REGISTRATION.CLOSED advisory. If the listening correspondent is available (running and reachable), it receives a

REGISTRATION.NOT\_CERTIFIED advisory. (Unlike the disallow listener calls in Table 7, these calls do not cause denial of subsequent registration requests.)

#### **DISALLOWING CERTIFIED DELIVERY**

- 5 As described before senders automatically accept all registration requests. This is true except when the sending program explicitly disallows certified delivery to a listening session. Calls that disallow a listener cancel existing certified delivery agreements with the listener session (on all subjects), and cause certified delivery software to automatically deny subsequent registration requests from the listener session.

10

When a sender has disallowed a listener, the events connected with registration do not occur. Instead, certified delivery software in the sender notifies the listener session that the request is disallowed. When certified delivery software in the listening program receives the rejection notice, it presents a REGISTRATION.NOT\_CERTIFIED advisory to the

15 listening session.

Allow listener calls supersede the effect of a previous disallow listener call, allowing subsequent registration requests from the listener session to succeed.

#### **20 NO RESPONSE TO REGISTRATION REQUESTS**

- It is possible that a registration request never reaches the delivery-tracking sender, or the acceptance notice never reaches the listening program (for example, because of network glitches, or termination of the sending program). After repeated attempts to register without response from the sender, certified delivery software in the listening
- 25 program presents a REGISTRATION.NO\_RESPONSE advisory to the listening session. After several attempts to register with no response, the listener stops sending requests.

#### **REUSABLE NAMES**

- Sessions that represent persistent correspondents require reusable names. Reusable
- 30 names must obey the syntax for subject names. Reusable names must not contain wildcard characters. Reusable names may not begin with reserved elements (such as \_INBOX, \_RV or \_LOCAL). For best performance, reusable names should be kept short--only a few characters, typically no more than three or four elements, and no more than 50 characters in total.

**LEDGER STORAGE MODE**

Each delivery-tracking session records information in a ledger, which occupies storage space within the application process. A session that represents a persistent  
5 correspondent must also keep a copy of the ledger in a file. The file-based ledger preserves certified delivery information beyond session (or process) termination and restart.

This feature has two associated costs:

10

The ledger file consumes disk space.

The application program pauses to update the ledger file at each significant event.

15

Transient correspondents need not pay these costs, because they do not use ledger files. However, keeping the ledger in process-based storage consumes process memory.

***Ledger Size***

20 The size of the ledger depends on several factors---the most important of which is the retention rate of stored data. That is, the ledger grows fastest in response to the cumulative length of incompletely delivered messages.

Program developers can estimate the expected size of the ledger, and must ensure that  
25 the process can allocate sufficient memory to contain it. For a file-based ledger, ensure that sufficient disk space is available as well, as memory requirements for the process application change when utilizing a file-based ledger.

**EVENT MANAGER**

30 The system's certified delivery depends on the event manager for timer and I/O events. When an application enables a delivery-tracking session, that session must be an event-managed session.

***No Synchronous Sessions***

Synchronous sessions are not valid for certified delivery calls and all delivery-tracking sessions must be asynchronous, event-managed sessions.

### *Distributed Queues*

5 The system also provides use of distributed queues for one-of-n certified delivery. In particular, the system provides for distributed queueing of messages along with certified/guaranteed delivery in a "one-of-n" delivery mechanism.

This delivery mechanism is illustrated in Figure 2 in which a single publisher 202 is publishing messages to three registered subscribers 204, 206 and 208 respectively. One  
10 of the subscribers, 206 is a large group of n-subscribers.

Distributed queueing addresses the problem that it is undesirable for all n-subscribers in registered subscriber 206 to get every message published by publisher 202. For example, it may be undesirable because each of the n-subscribers in group 206 will take  
15 an action. In addition, if each subscriber is to receive the message (and possibly respond to it) this will consume additional network bandwidth.

Nonetheless, it is imperative (hence the need for certified/guaranteed delivery) for at least one of the n-subscribers in group 206 to receive the message. I.e., ideally the  
20 system should deliver the message to only one of the n-subscribers 206. This type of situation arises where a large number n of subscribers 206 is required to provide the desired level of fault tolerance and/or load balancing. Fault tolerance is important in situations where applications may be unstable or message delivery is absolutely critical.

25 In the system of the invention, each subscriber application in the group 206 operates by sending messages to another of the n-subscribers in the group 206 acting as a scheduler giving an indication of its weight. The scheduler then responds by sending the message to the particular subscriber in the group with the greatest weight. Greater details of how this is accomplished follow directly below.

30 Accordingly, a distributed queue of subscribing database servers 206 can accept certified messages that represent tasks (updates and queries). The system assigns each task to exactly one of the servers, while the group of servers and the distribution of tasks remains completely transparent to the client processes.

***Queue Members***

The member sessions of a distributed queue all share the same reusable correspondent name indicating that they are members of the queue with that name. Each member of a distributed queue listens for the same subjects--yet even when n members listen, for each inbound message (or task), only one member processes the message.

***Member Roles--Worker and Scheduler***

As used herein with respect to queueing and queued delivery, the terms "listener" and "worker" are used interchangeably. Each distributed queue member session can have two distinct roles--as a worker, and as a potential scheduler.

In the listener or worker role, queue member sessions support a limited subset of certified delivery calls; members can listen to a subject, override automatic confirmation of delivery and confirm delivery. Queue member sessions do not support any other certified delivery calls (in particular, calls associated with sending certified messages). However, they do support all standard calls (for example, sending ordinary messages).

The system includes fault tolerance software that maintains exactly one active scheduler in each queue; if the scheduler process terminates, another member assumes the role of scheduler. The queue member session in the scheduler role assigns inbound tasks to listeners in the queue. (A scheduler can assign tasks to its own listener component, but only does so when all other listeners are busy.)

***The Scheduler as a Fault-Tolerant Component***

Although any queue member has the potential to become the scheduler, fault tolerance software maintains exactly one scheduler at all times. Fault tolerance parameters guide the software to select the most suited member as scheduler.

Scheduler weight represents the ability of a member session to fulfill the role of scheduler, relative to other members of the same queue, i.e., the greatest availability or unused member resources. The queue members use relative scheduler weight values to



elect one member as the scheduler; members with higher scheduler weight take precedence.

- 5 The active scheduler sends heartbeat messages at the interval specified by the user. Heartbeat messages inform other members that a member is acting as the scheduler. All sessions in the queue must specify the same scheduler heartbeat interval.

- 10 In addition, all sessions in the queue must specify the same scheduler activation interval. When the heartbeat signal from the scheduler has been silent for this interval the queue member with the greatest scheduler weight takes its place as the new scheduler.

#### *Assigning Tasks to Workers*

- 15 The scheduler assigns each task to a worker or listener (another queue member session). That worker or listener alone processes the task message in a data callback function.

#### *Worker Weight*

- 20 Relative worker or listener weights assist the scheduler in assigning tasks. When the scheduler receives a task, it assigns the task to the available worker or listener with the greatest worker or listener weight.

- 25 Enabling a session as a queue member tacitly sets its worker or listener weight parameter to 1. That is, all members implicitly have the same worker or listener weight, unless program code explicitly changes the worker or listener weight.

#### *Availability*

- 30 When the scheduler receives a task, it assigns the task to the available worker listener with the greatest listener weight.

A worker listener is considered available unless either of these conditions are true:

The pending tasks assigned to the worker or listener exceed its task capacity.

The worker or listener session is the scheduler. (The scheduler assigns tasks to its own worker or listener only when all other workers or listeners are busy.)

***Task Capacity***

Task capacity is the maximum number of tasks that a worker or listener can accept. When the number of accepted tasks reaches this maximum, the worker or listener cannot accept additional tasks until it completes one or more of them.

When the scheduler receives a task, it assigns the task to the worker or listener with the greatest worker or listener weight--unless the pending tasks assigned to that worker or listener exceed its task capacity. When the preferred worker or listener has too many tasks, the scheduler assigns the new inbound task to the worker or listener with the next greatest worker or listener weight.

Enabling a session as a queue member tacitly sets its worker or listener task capacity to 1. Programmers can tune task capacity based on two factors:

Multi-tasking program on multiprocessing hardware.

On a multiprocessing computer, a multi-threaded program that devotes  $n$  threads and  $n$  processors to inbound tasks has task capacity  $n$ .

Communication time lag.

In most distributed queue applications, the communication time is an insignificant fraction of the task turnaround time. That is, the time required to assign a task and signal its completion is very small compared to the time required to process the task itself. For example, when average task turnaround time is 2000 milliseconds, of which communication time contributes only 10 milliseconds to the total, then task capacity is the same as the number of processors or threads.

However, in some situations communication time can be significant--for example, when the queue members are distributed at distant sites connected by a WAN. When communication time is significant, the meaning of task capacity changes; instead of signifying the number of tasks that a listener can process concurrently, it signifies the

number of tasks that can fill the listener's capacity despite the communication time lag. For example, when the average task turnaround time is 1500 milliseconds, of which the average task processing time contributes 1000 milliseconds to the total, then setting the task capacity to 3 minimizes the listener's idle time between tasks.

- 5 When tuning task capacity to compensate for communication time lag, balance is critical. Underloading a listener (by setting its tasks capacity too low) can cause the listener to remain idle while it waits for the schedule to assign its next task. Conversely, overloading a listener (by setting its task capacity too high) can cause some assigned tasks to wait, while other listeners that might have accepted those tasks remain idle.

10

#### **TASK SCHEDULING**

- In a further application of this invention, the broad concepts of distributed queuing can be applied to scheduling tasks for different task doing applications. In this application an application can be either a scheduler or a worker or both. Each worker is assigned a weight indicating its ability to do work, usually the number of tasks it can do simultaneously. Typically, workers assign their own weights.

15

20

One application/member of a group becomes the scheduler. Once this occurs, all other applications become designated workers only. The scheduler becomes both a worker and the scheduler.

25

When a task is received by the group (the scheduler) it assigns the task to the worker with the highest "weight" or ability to do tasks. The worker then calls back to the scheduler accepting the task and, upon completion, returns a call to the scheduler indicating this fact. In certain instances, the call back to the scheduler includes both an acceptance and a notification of task completion.

30

Two Appendices, A and B are attached. These appendices include detailed C coding information respectively for Certified messaging and for message queuing.

All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

The invention now being fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from its spirit or scope.

## **Appendix A: Certified Message Delivery (Programming Details for C Programmers)**

As indicated previously, even though some communications are highly reliable, certain applications require even stronger assurances of delivery. Certified delivery features offers greater certainty of delivery even in situations where processes and their network connections are unstable.

This Appendix A provides programming details for C programmers wishing to implement Certified message Delivery. The Appendix provides, in Table A1, an overview listing of Certified's messaging Deliver Datatypes and Functions. Each Datatype or Function is then described in greater detail with Cross-references to related Datatypes or Functions.

15

### **Certified Message Delivery CAPI**

The following table summarizes the datatypes and functions in the certified message delivery C API.

20

Table A1: Certified Message Delivery: Datatypes and Functions

Item	Description
<code>rvcm_Enable ( )</code>	Enable an existing session for delivery tracking.
<code>rvcm_ListenSubject ( )</code>	Listen for broadcast messages, and request certified delivery whenever available.
<code>rvcm_ListenInbox ( )</code>	Open a delivery-tracking inbox to listen for point-to-point messages, and request certified delivery whenever available.
<code>rvcm_Callback</code>	Function type of callback functions that receive and process inbound messages for delivery-tracking listeners.
<code>rvcm_ListenId</code>	Certified listening calls return identifiers of this type.
<code>rvcm_seq</code>	Certified messages bear sequence numbers of this type.
<code>rvcm_close ( )</code>	Close a delivery-tracking endpoint; stop listening for messages on it.
<code>rvcm_Send ( )</code>	Send a labeled message, and track delivery to cooperating listeners.
<code>rvcm_SendWithReply ( )</code>	Send a labeled request message, and track delivery to cooperating listeners.
<code>rvcm_AddListener ( )</code>	Pre-register an anticipated listener.

Table A1: Certified Message Delivery: Datatypes and Functions (con't.)

Item	Description
<code>rvcn_RemoveListener()</code>	Cancel certified delivery of a subject to a listening correspondent.
<code>rvcn_DisallowListener()</code>	Cancel certified delivery of all subjects to a listening correspondent, and deny subsequent registration requests.
<code>rvcn_AllowListener()</code>	Invite a receiver to reinstate certified delivery for its listeners.
<code>rvcn_NoAutoConfirm()</code>	Override automatic confirmation of delivery.
<code>rvcn_confirm()</code>	Confirm delivery of a certified message.
<code>rvcn_ReviewLedger()</code>	Summarize the delivery status of messages in the ledger,
<code>rvcn_ReviewCallback</code>	Function type of callback functions that process ledger information for <code>rvcn_ReviewLedger()</code> .
<code>rvcn_SyncLedgerFile()</code>	Synchronize the ledger file.
<code>rvcn_Error</code>	Datatype. Enumerates error codes for the certified message delivery API.
<code>rvcn_ErrorText()</code>	Return a text string describing an error code.

**rvcm\_Enable()****Function****Declaration**

```
5  rvcm_Error rvcm_Enable (  
    rv_Session  session,  
    rv_Name     name,  
    rv_Name     reserved,  
    char*       ledgerFile,  
10  rv_Boolean  requireOldMsgs
```

**Purpose**

Enable an existing session for delivery tracking.

15

**Remarks**

All other rvcm functions require an enabled session as an argument. Programs must call rvcm\_Enable ( ) before any other calls related to certified delivery.

20

A user can use an enabled session for both certified and non-certified communications. For example, an enabled session supports calls to rvcm\_Send ( ) and rv\_Send ().

25 Once a session is enabled for certified delivery, it remains enabled until terminated with rv\_Term ().The user cannot subsequently change the certified delivery parameters of the session.

**Name**

30 rvcm\_Enable ( ) promotes its session argument to a delivery-tracking session.

If name is NULL, then rvcm\_Enable ( ) generates a unique, non-reusable name for this session.



If name is non-NULL, then the session binds that name. A correspondent can persist beyond session termination only when it has both a reusable name and a file-based ledger.

## 5 Ledger File

Every delivery-tracking session stores the state of its certified communications in a ledger, which is stored in memory associated with the process.

- 10 If ledgerFile is NULL, then this session uses a only process-based ledger. When the session or process terminates, all information in the ledger is lost.

- If ledgerFile specifies a valid file name, then this session uses that file for ledger storage. If the session or process terminates with incomplete certified  
15 communications, the ledger file records that state. When a new session binds the same reusable name, it reads the ledger file and continues certified communications from the state stored in the file.

- Even though a session uses a ledger file, it may sometimes replicate parts of the  
20 ledger in process-based storage for efficiency; however, programmers cannot rely on this replication.

- If the operating system supports raw storage devices (also called raw partitions), the user can specify such a device as the ledger file.

25

An optional prefix determines whether writing to the ledger file is a synchronous operation:

- To specify synchronous writing (the default), either supply an ordinary file  
30 name, or prepend the string sync\* to the file name; for example, "myLedger" (implicit) or "sync\*/local/myLedger" (explicit). Each time a ledger item is written, the call does not return until the data is safely stored in the file system.

- To specify asynchronous writing, prepend the string `nosync*` to the file name; for example, "`nosync*/local/myLedger`". The ledger file might not accurately reflect program state in cases of hardware or operating system kernel failure.

5 A program that uses an asynchronous ledger file can explicitly synchronize it by calling `rvcm_SyncLedgerFile()`, described below.

#### Parameters

10

Parameter	Description
session	Enable this session for certified delivery tracking.
name	<p>Bind this reusable name to the session, so the session represents a persistent correspondent with this name.</p> <p>If non-Null, the name must conform to the syntax rules for subject names. It cannot begin with reserved tokens. It cannot be a non-reusable name generated by another call to <code>rvcm_Enable()</code>.</p> <p>If this argument is NULL, then <code>rvcm_Enable()</code> generates a unique, non-reusable name for the duration of the session.</p>
reserved	This parameter is reserved for future enhancement. The user must supply NULL for foilNard compatibility.

Parameter	Description
ledgerFile	<p>If this argument is non-NULL, then this session uses a file-based ledger. The argument must represent a valid file name. Actual locations corresponding to relative file names conform to operating system conventions.</p> <p>Prepending nosync* to the file name specifies asynchronous output to the file system. sync* or no prefix specifies synchronous output (flushed before each output call returns).</p> <p>If this argument is NULL, then this session uses a process-based ledger.</p>
requireOldMsgs	<p>This parameter indicates whether a persistent correspondent requires delivery of messages sent to a previous session with the same name, for which delivery was not confirmed. Its value affects the behavior of other delivery-tracking senders.</p> <p>If this parameter is RV_TRUE and name is non-NULL, then this session requires certified senders to retain unacknowledged messages sent to this persistent correspondent. When this session begins listening to the appropriate subjects, the senders can complete delivery. (It is an error to supply RV_TRUE when name is NULL.)</p> <p>If this parameter is RV_FkLSr., then this session does not require certified senders to retain unacknowledged messages. Certified senders may delete those messages from their ledgers.</p>

**Errors**

<b>RVCM Error Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_SESSION_NAME</b>	The function received an ill-formed reusable name.
<b>RVCM_ERR_NO_MEMORY</b>	The function could not complete because the operating system denied its request to allocate storage.
<b>RVCM_ERR_FILE_IO_ERROR</b>	rvcm_Enable ( ) encountered an error while opening the ledger file. For example, an explicitly named directory does not exist.
<b>RVCM_ERR_FILE_NO_PERMISSION</b>	File privileges are insufficient for rvcm_Enable ( ) to open the ledger file.
<b>RVCM_ERR_LEDGER_NAME_CONFLICT</b>	rvcm_Enable ( ) received NULL as the name parameter, but a non-NULL value as the ledgerFile parameter.
<b>RVCM_ERR_PARAMETER_CONFLICT</b>	<p>The function received conflicting values for parameters.</p> <p>rvcm_Enable ( ) received RV_FALSE as its requireOldMsgs parameter, and NULL as its name parameter. A non-reusable name implies a transient correspondent, which cannot have backlog messages.</p>

RVCM Error Code	Indicates
RVCM_ERR_FILE_NOT_LEDGER_OWNER	The reusable name recorded in the file differs from the name of this session. <code>rvcm_Enable ( )</code> stopped reading the file.
RVCM_ERR_CORRUPT_LEDGER_FILE	The ledger file is corrupt. <code>rvcm_Enable ( )</code> could read only part of the ledger file into process-based memory. Some information may be lost.
RVCM_ERR_SESSION_ALREADY_ENABLED	<code>rvcm_Enable ( )</code> received a session that is already enabled for delivery tracking. It is illegal to enable a session more than once.

### Coding Example

```

5  cm_err = rvcm_Enable(sess, "CM_EXAMPLE", NULL,
    "my_ledger_file", RV_TRUE);

```

```

    if (cm_err != RVCM_OK)
    {
10      fprintf(stderr, 'Can't enable CM session--%s\n',
        rvcm_ErrorText (sess, cm_err) );
        exit (-1);
    }

```

15 See Also

`rvcm_SyncLedgerFile()`, below

20 `rvcm_ListenSubject()`  
*Function*

**Declaration**

```

rvcm_Error rvcm_ListenSubject (
    rv_Session      session,
5   rvcm_LisCenId*  listenid,
    rv_Name         subject,
    rvcm_Callback   dataCallbackFn,
    rv_Opaque       closureArg )

```

**10 Purpose**

Begin listening for messages that match the subject, and request certified delivery whenever available. Whenever a message arrives, the callback function receives it.

**15 Remarks**

This function is parallel to `rv_ListenSubject ( )`--it creates an endpoint to receive messages with matching subjects. The endpoint receives both labeled messages and ordinary messages.

20

When a labeled message arrives from an unfamiliar delivery-tracking session, the receiving session requests certified delivery for the subject. If the sending session accepts the request, then the two sessions cooperate to certify delivery of subsequent messages with this subject.

25

Unlike ordinary listening endpoints, the user cannot maintain more than one delivery-tracking listening endpoint per subject. When one endpoint is already open, subsequent calls to `rvcm_ListenSubject()` with the same subject return an error. (This restriction applies to each delivery-tracking session; however, a program with several

30 delivery-tracking sessions can open independent delivery-tracking listeners with identical subjects.)

Unlike `rv_ListenSubject()`, the user cannot use `rvcm_ListenSubject()` to listen to wildcard subjects.

The software automatically confirms message delivery when the data callback function returns.

5

### Parameters

Parameter	Description
session	A delivery-tracking session.
listenId	When <code>rvcm_ListenSubject()</code> returns (without error), this location contains a handle denoting the new endpoint. To stop listening on the subject, pass this handle to <code>rvcm_Close()</code> .
subject	Listen for messages with this subject name.  Wildcard subjects are illegal.
dataCallbackFn	When a message arrives, pass it to this callback function.
closureArg	Pass this closure argument to the callback function. This argument must be a pointer, but it can point to any type of data. It contains any information needed by the callback function. This argument is treated as an opaque closure, forwarding it to the callback function without accessing its value.

**Errors**

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_ARG</b>	The function received an illegal argument. rvcm_ListenSubject() received either a NULL callback function, or a NULL listenid pointer.
<b>RVCM_ERR_NO_MEMORY</b>	The function could not complete because the operating system denied its request to allocate storage.
<b>RVCM_ERR_BAD_SUBJECT</b>	rvcm_ListenSubject() received an ill-formed subject name. Either it is NULL, or contained too many total characters, too many characters in an element, too many elements, a wildcard character, or an illegal prefix.
<b>RVCM_ERR_DUPLICATE_SUBJECT</b>	rvcm_ListenSubject() Can maintain at most one open listening endpoint per subject (per session); it cannot open a second listening endpoint for this subject.
<b>RVCM_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.



**Coding Example**

```

cm_err = rvcm_ListenSubject(sess, &listenId, subject,
                           CM_callback, myClosure);
    if (cm_err != RVCM_OK)
5      fprintf(stderr, "error %s listening to \"%s\"\n",
              rvcm_ErrorText (sess, cm_err), subject);

```

**See Also**

```

10  rvcm_Callback;
    rvcm_ListenId;
    rvcm_ListenInbox();
    rvcm_Close(), all described below

```

15

```

rvcm_ListenInbox()

```

**Function**

```

20  rvcm_Error rvcm_ListenInbox (

        rv_Session      session,
        rvcm_ListenId*  listenid,
        rv_Name         inbox,
25  rv_Size             inboxLimit,
        rvcm_Callback   dataCallbackFn,
        rv_Opaque       closureArg)

```

**Purpose**

```

30  Open an inbox and begin listening for point-to-point messages addressed to it.
    Request certified delivery whenever available. Whenever a message arrives, pass it to
    the callback function.

```

**Remarks**

This function is parallel to *rv\_ListenInbox ( )*--it creates an inbox to receive point-to-point messages. The inbox receives both labeled messages and ordinary messages.

- 5 When a labeled message arrives from an unfamiliar delivery-tracking session, the receiving session requests certified delivery for the inbox name. If the sending session accepts the request, then the two sessions cooperate to certify delivery of subsequent messages to this inbox.

- 10 Certified delivery to an inbox is limited to the duration of the inbox. Once the users closes an inbox or terminates its session, the inbox and its name become obsolete; the user can never open another inbox with the same name. Since the system can never complete delivery of messages addressed to an obsolete inbox, it automatically deletes stored messages when it detects that an inbox has become obsolete.

- 15 The system automatically confirms message delivery when the data callback function returns.

#### Parameters

Parameter	Description
session	A delivery-tracking session.
listenId	When <i>rvcm_ListenInbox ( )</i> returns (without error), this location contains a handle denoting the new inbox. To stop listening, pass this handle to <i>rvcm_Close ( )</i> .
inbox	Location to store the generated name of the new inbox. The allocated space must be at least <i>RV_t,mX_INBOX_NAME</i> (currently 100 bytes).
inboxLimit	Number of bytes allocated to store the new inbox name.
dataCallbackFn	When a message arrives, pass it to this callback function.

Parameter	Description
closureArg	Pass this closure argument to the callback function. This argument must be a pointer, but it can point to any type of data. It contains any information needed by the callback function. the system treats this argument as an opaque closure, forwarding it to the callback function without accessing its value.

### Errors

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument. rvcm_ListenInbox ( ) received either a NULL inbox name pointer, a NULL callback function, or a NULL listenid pointer.
RVCM_ERR_NO_MEMORY	The function could not complete because the operating system denied its request to allocate storage.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

5

### Coding Example

```
char inboxName [RV_MAX_INBOX_NAME];
```

```
cm_err = rvcm_ListenInbox(sess, &listenId, inboxName, sizeof(inboxName),
                          CM_callback, myClosure);
```

```
5      if (cm_err != RVCM_OK)
          fprintf(stderr, "error %s listening to certified inbox.\n",
                  rvcm_ErrorText(sess, cm_err));
```

See Also,

```
10  rvcm_Callback, below
    rvcm_ListenId, below
    rvcm_ListenSubject(), above
    rvcm_Close(), below.
```

15

**rvcm\_Callback**

*Datatype*

20 **Declaration**

```
void* rvcm_Callback (
    rv_Session      session,
    rv_Name         subject,
    rv_Name         replyName
25  rvmsg_Type      msgType,
    rvmsg_Size      msgSize,
    rvmsgData       msg,
    rvcm_Seq        sequenceNum,
    rv_Name         senderName,
30  rv_Opaque       closureArg )
```

**Purpose**

rvcm\_Callback is the function type of data callback functions to delivery-tracking listeners. Applications define functions of this type to receive inbound messages and take appropriate actions.

**5    Remarks**

This function type is parallel to rv\_Callback. Notice that its function signature includes two additional parameters, senderName and sequenceNum, to receive the tracking data that labels the inbound message. Application programs can use these arguments for testing and auditing.

**10**

The system automatically confirms message delivery when the data callback function returns.

**15**

The user can write several callback functions to process the various kinds of messages that the application expects to receive. The user can use the same callback function to process messages at several endpoints. Callback functions can take any action in processing a message, except for the following restrictions:

**20**

- Callback functions must not attempt to modify the data (the values of the parameters msg, subject, reillyName and senderName) in any manner. The callback function receives data through pointers; the actual data resides in memory that does not belong to the application. The data pointers remain valid only until the callback function returns.

**25**

- The data callback functions must return promptly.

**Parameters**

<b>Parameter</b>	<b>Description</b>
session	This parameter receives the current session.
subject	<p>This parameter receives the destination subject name of the inbound message.</p> <p>Do not modify this value. This pointer remains valid only until the callback function returns.</p>
replyName	<p>If the inbound message carries a name for replies, this parameter receives it. Otherwise NULL.</p> <p>Do not modify this value. This pointer remains valid only until the callback function returns.</p>
msgType	This parameter receives the datatype of the message.
msgSize	This parameter receives the size (in bytes) of the message.
msg	<p>This parameter receives a pointer to the message data.</p> <p>Do not modify this value. This pointer remains valid only until the callback function returns.</p>
sequenceNum	If the message is certified, this parameter receives the sequence number that the sender assigned to the message. Otherwise, this parameter receives zero.
senderName	<p>If the message is labeled, this parameter receives the name of the delivery-tracking session that sent the message. Otherwise, this parameter receives NULL.</p> <p>Do not modify this value. This pointer remains valid only until the callback function returns.</p>

closureArg	This parameter receives a closure argument supplied by the application when it began listening. This argument is a pointer, but it can point to any type of data. It contains any information needed by the callback function. the system treats this argument as an opaque closure, forwarding it to the callback function without accessing its value.
------------	--

### Coding Example

- 5 This example code illustrates a data callback function for receiving messages with certified delivery.

```

void
CM-callback (
10     rv_Session session,
        rv_Name subject,
        rv_Name replyName,
        rvmsg_Type msgType,
        rvmsg_Size msgSize,
15     rvmsg_Data msg,
        rvcm_Seq seqNumber,
        rv_Name sender,
        rv_Opaque myClosureArg )
{
20
    printf("Received: subject=%s, reply=%s, message=",
           subject, (replyName!=NULL ? replyName : "<none>"));
    rvmsg_PrintItem(session, msgType, msgSize, msg, NULL);
    printf("\n");
25    printf(" sequence number=%ld, sender=%s\n",
           seqNumber, (sender!=NULL ? sender : "<none>"));

```

```
        fflush(stderr);  
    }
```

### See Also

5

rvcm\_ListenId; rvcm\_Seq; and rvcm\_Close(), below.

### rvcm\_ListenId

10

#### *Datatype*

#### Declaration

```
typedef void* rvcm_ListenId;
```

15

#### Purpose

The rvcm\_ListenSubject ( ) and rvcm\_ListenInbox ( ) functions return a handle of type rvcm\_ListenId. To stop listening for the corresponding information, pass this handle to rvcm\_Close ( ).

20

#### Remarks

an rvcm\_ListenId is not meaningful outside of the session in which it was created. Each rvcm\_ListenId is a unique handle representing an association between a subject and a callback function. Use rvcm\_ListenId only within the local program that receives it from one of the listening functions, and treat it as opaque.

25

### rvcm\_Seq

#### *Datatype*

30

#### Declaration

```
typedef unsigned long rvcm_Seq;
```

#### Purpose



Sequence number of a labeled message.

#### Remarks

- 5 Sequence numbers are limited to 32 bits on all platforms (even platforms that support 64-bit integers).

**rvcm\_Close()**

#### 10 *Function*

#### Declaration

- rvcm\_Error rvcm\_Close (  
    rv\_Session session,  
15 rvcm\_ListenId listenid

#### Purpose

Close a delivery-tracking endpoint; stop listening for messages on it.

#### 20 Remarks

This function is parallel to rv\_Close ().

- Cooperating senders receive a REGISTRATION. CLOSED advisory, indicating that the delivery tracking agreement is no longer in effect. Senders receive a DELIVERY.  
25 FAILED advisory for each undelivered message to the closed endpoint, and the system removes undelivered messages from the sender's ledger.

The system deletes the listener's ledger items corresponding to the closed subject.

- 30 When rvcm\_Close ( ) closes an endpoint, it generates a HOST.LISTEN.STOP advisory message to inform other applications that this application has stopped listening to the subject.

It is important that a persistent listener close a delivery-tracking endpoint when it no longer requires certified delivery of the corresponding subject--and only then. Open endpoints cause certified senders to store messages in the ledger while awaiting delivery confirmation from the sender. From the sender's perspective, a persistent listener that exits without closing its listening endpoints appears the same as a listener that terminates abnormally; the sender continues to store messages awaiting the return of the Listener process. Once an endpoint is closed, senders do not store certified messages for that listener, and successive listener processes with the same correspondent name do not receive certified delivery of messages sent in the interim.

10

### Coding Example

Close endpoints when the application is finished receiving data. Closing endpoints lets TiB/Rendezvous software re-use the associated storage resources. After closing an endpoint, delete all references to it, to guard against closing it twice.

15

It is illegal to close the same endpoint more than once. On some platforms, the error `RVCM_ERR_NONEXISTENT_ID` results; on other platforms, the result can be a fatal error

20 (because it references dynamically allocated memory that has been freed).

This code fragment illustrates the recommended idiom for closing endpoints:

```
25      if (foo->listenId != NULL)
          (rvclm_Close(foo->listenId);
           foo->listenId = NULL; }
```

**Parameters**

Parameter	Description
session	The delivery-tracking session that created the endpoint.
listenId	Close the endpoint that this handle denotes.

**Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument. rvcm_Close() received a NULL listenId pointer.
RVCM_ERR_NONEXISTENT_ID	rvcm_Close () received a NULL listenId pointer either it is NULL, or it points to something other than an rvcm_ListenId, or it points to an endpoint that has already been closed.
RVCM_ERR_NO_MEMORY	The function could not complete because the operating system denied its request to allocate storage.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

**See Also**

rvcm\_ListenId, above.

rvcm\_Send()

**5 Function****Declaration**

```

rvcm_Error rvcm_Send (
    rv_Session      session,
10    rv_Name        subject,
    rvmsg_Type      msgType,
    rvmsg_Size      msgSize,
    rvmsg_Data      msg,
    unsigned long    timeLimit,
15    rvcm_Seq*      sequenceNum )

```

**Purpose**

Send a labeled message, and track delivery to cooperating listeners.

**20 Remarks**

This function is parallel to rv\_Send (). Notice that its signature includes two additional parameters, timeLimit and SequenceNum.

Use timeLimit to specify the duration of the message (in seconds). The system retains  
25 the message in its ledger until either it receives delivery confirmation from all cooperating listeners, or the timeLimit expires. If the time limit expires before delivery is complete, the system removes the message from the ledger, and generates a DELIVERY. FAILED advisory message listing the cooperating listeners that did not confirm delivery of the message.

30

We recommend a timeLimit value greater than 60 seconds, since the domain holds messages for 60 seconds.

`rvcm_Send ( )` labels the message with the name of the delivery-tracking session and a sequence number. `rvcm_Send ( )` passes the sequence number back to the caller in its `sequenceNum` parameter (the user can use this number for auditing).

- 5 Each sending session maintains a separate sequence for each subject it sends. As a result, receivers can uniquely identify each labeled message by the three data callback arguments `subject`, `senderName` and `sequenceNum`.

- 10 When `msg` has self-evident length, the user may supply zero for `msgSize` (the system computes the actual size automatically). Types with self-evident size are `RVMSG_RVMSG`, `RVMSG_STRING` (when the string is NULL-terminated) and `RVMSG_ENCRYPTED`. All other types require an explicit size argument in this call.

#### 15 `rvcm_Send()`

`rvcm_Send ( )` copies its arguments. After `rvcm_Send ( )` returns, the user may free or reuse the storage (for example, a message buffer).

#### 20 **Warning**

It is illegal to send messages to wildcard subject names. Although `rvcm_Send ( )` does not prevent the user from sending illegally to wildcard subjects, the results are unpredictable.

#### 25 **Parameters**

Parameter	Description
<code>session</code>	A delivery-tracking session.
<code>subject</code>	Send the message to this subject name or inbox.
<code>msgType</code>	Datatype of the message data.

msgSize	Length of the data (in bytes).
msg	Location of the data to send.
timeLimit	<p>Retain the message in the ledger, and continue attempts at delivery either until completion of delivery or until this time limit (in seconds) expires.</p> <p>Zero is a special value, indicating no time limit; the message remains in the ledger until delivery is complete to all certified listeners.</p> <p>A non-zero value less than 60 seconds adds no advantage over ordinary reliable message delivery, since rvd retains and retransmits messages for 60 seconds.</p>
sequenceNum	This location receives the sequence number of this message.

**Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.

RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument. rvcm_Send () or rvcm_SendWithReply () received either a NULL subject, or a NULL sequence number pointer
RVCM_ERR_NO_MEMORY	The function could not complete because the operating system denied its request to allocate storage.
RVCM_ERR_BAD_SUBJECT	rvcm_Send () or rvcm_SendWithReply () received an ill-formed subject name.  Either it contained too many total characters, too many characters in an element, or too many elements.

RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.
------------------------------	--

**Coding Example**

```
int time_limit = 600; /* 600sec = 10min */
```

5

```
cm_err = rvcm_Send(sess, subject, type, sizeof(msg), msg,
                  time_limit, &seq_no);
```

```
if (cm_err == RVCM_OK)
```

```
    fprintf(stderr, "Sent sequence num %d\n", seq_no);
```

10 else

```
    fprintf(stderr, "Error while sending certified message: %s\n",
            rvcm_ErrorText (sess, cm_err) );
```

**See Also**

15 rvcm\_Seq, above

```
rvcm_SendWithReply(), below.
```

```
rvcm_SendWithReply()
```

**Function**

20

**Declaration**

```
rvcm_Error rvcm_SendWithReply (
```

```
    rv_Session      session,
```

```
    rv_Name         subject,
```

25 rv\_Name replyName,

```
    rvms_g_Type     msgType,
```

```
    rvmsg_Size      msgSize,
```

```
    rvmsg_Data      msg,
```

```
    unsigned long timeLimit,
```



rvcm\_Seq\*                      sequenceNum

### Purpose

Send a labeled request message, and track delivery to cooperating listeners. A request  
5 message includes a reply name as a return address for response messages.

### Remarks

This function is parallel to rv\_SendWithReply (). Notice that its signature includes  
two additional parameters, timeLimit and sequenceNum.

10

The reply name must be the subject name of an open listening endpoint (either  
broadcast or inbox). An application may receive zero, one or several responses to a  
request message. Before the user calls rvcm\_SendWithReply ( ) the user must ensure  
that the appropriate application components are listening to the reply name.

15

rvcm\_SendWithReply ( ) is a non-blocking function. It returns immediately, and the  
callback function receives any replies asynchronously. A reply is not guaranteed (for  
example, if the receiver does not send any reply).

20

Use timeLimit to specify the duration of the message. the system retains the message  
in its ledger until either it receives delivery confirmation from all cooperating  
listeners, or the timeLimit expires. If the time limit expires before delivery is  
complete, the system removes the message from the ledger, and generates a  
DELIVERY.FAILED advisory message listing the cooperating listeners that did not  
25 confirm delivery of the message.

A timeLimit value greater than 60 seconds is recommended, since the domain holds  
messages for 60 seconds.

30

*rvcrn\_Send WithReply()*

rvcm\_SendWithReply() labels the message with the name of the delivery-tracking  
session and a sequence number. rvcm\_SendWithReply() passes the sequence number

back to the caller in its sequenceNum parameter (the user can use this number for auditing).

- 5 Each sending session maintains a separate sequence for each subject it sends. As a result, receivers can uniquely identify each labeled message by the three data callback arguments subject, senderName and sequenceNum.

- 10 When msg has self-evident length, the user may supply zero for msgSize (the system computes the actual size automatically). Types with self-evident size are RVMSG\_RVMSG, RVMSG\_STRING (when the string is NULL-terminated) and RVMSG\_ENNCRYPTED. All other types require an explicit size argument in this call.

- 15 rvcm\_SendWithReply() copies its arguments. After rvcm\_SendWithReply() returns, the user may free or reuse the storage (for example, a message buffer).

#### Warning

- 20 It is illegal to send messages to wildcard subject names. Although the function rvcm\_SendWithReply() does not prevent the user from sending illegally to wildcard subjects, the results are unpredictable.

#### Parameters

Parameter	Description
Session	A delivery-tracking session.
Subject	Send the message to this subject name or inbox.

ReplyName	<p>Subject name for replies to this request message (similar to a return address on a letter, and delivered to receiving applications in the replyName argument of the callback function).</p> <p>The reply name may be an inbox or subject name. Before calling <code>rvcm_SendWithReply()</code>, ensure that a listening endpoint is already open for the reply name.</p>
MsgType	Datatype of the message data.
MsgSize	Length of the data (in bytes).
Msg	Location of the data to send.
timeLimit	<p>Retain the message in the ledger, and continue attempts at delivery either until completion of delivery or until this time limit (in seconds) expires.</p> <p>Zero is a special value, indicating no time limit; the message remains in the ledger until delivery is complete to all certified listeners.</p> <p>A non-zero value less than 60 seconds adds no advantage over ordinary reliable message delivery, since <code>rvd</code> retains and retransmits messages for 60 seconds.</p>
sequenceNum	This location receives the sequence number of this message.

**Errors**

**See Also**

rvcm\_Seq, page 203; and  
rvcm\_SendWithReply(), above.

5

**rvcm\_AddListener()****Function****Declaration**

10 rvcm\_Error rvcm\_AddListener (  
    rv\_Session session,  
    rv\_Name name,  
    rv\_Name subject )

15 **Purpose**

Pre-register an anticipated listener.

**Remarks**

20 Some sending applications can anticipate requests for certified delivery--even before  
the listening applications begin running. In such situations, the sender can pre-  
register listeners, so the system begins storing outbound messages in the sender's  
ledger; when the listener requests certified delivery, it receives the backlogged  
messages.

25 If the correspondent with this name already receives certified delivery of this subject  
from this sender session, then rvcm\_AddListener() has no effect.

If the correspondent with this name is disallowed, then rvcm\_AddListener() returns an  
error. The user can call rvcm\_AllowListener() to supersede the effect of a prior call to  
30 rvcm\_DisallowListener(); then call rvcm\_AddListener() again.

**Parameters**

Parameter	Description
session	A delivery-tracking session.
subject	Anticipate a listener for this subject.
name	Anticipate a listener from a correspondent with this reusable name.

*rvcm\_AddListener()*

### Errors

5

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_SESSION_NAME	The function received an ill-formed reusable name.
RVCM_ERR_BAD_ARG	The function received an illegal argument.  <i>rvcm_AddListener()</i> received a NULL listener name.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

RVCM_ERR_BAD_SUBJECT	The function received an ill-formed subject name.  Either it is NULL, or contained too many total characters, too many characters in an element, too many elements, or an illegal prefix.
RVCM_ERR_DISALLOWED_LISTENER	rvcm_AddListener() cannot add this listener because it is disallowed. First call rvcm_AllowListener().

**Coding Example**

```

cm_err = rvcm_AddListener(sess, "LISTENER_17", subject);
if(cm_err != RVCM_OK)
5      {
        fprintf(stderr, "Can't add CM listener:\n %s\n",
                rvcm_ErrorText(sess, cm_err));
        exit(-1);
      }
10

```

**See Also**

rvcm\_RemoveListener(), below.

15 rvcm\_RemoveListener()

**Function****Declaration**

```

20 rvcm_Error rvcm_RemoveListener (
        rv_Session      session,
        rv_Name         name, /* listening correspondent name */
        rv_Name         subject )

```

**Purpose**

Unregister a specific listener at a specific correspondent, and free associated storage in the sender's ledger.

**5 Remarks**

This function cancels certified delivery of the specific subject to the correspondent with this name. The listening correspondent may subsequently re-register for certified delivery of the subject. (In contrast, `rvcm_DisallowListener()` cancels certified delivery of *all* subjects to the correspondent, *and* prohibits re-registration.)

10

Senders usually call this function when the ledger item for a listening correspondent has grown very large. Such growth indicates that the listener is not confirming delivery, and may have terminated. Removing the listener reduces the ledger size by deleting messages stored for the listener.

15

When a sending program calls this function, certified delivery software in the sender behaves as if the listener had closed the endpoint for the subject. The sending program deletes from its ledger all information about delivery of the subject to the correspondent with this name. The sending program receives a REGISTRATION.

20

CLOSED advisory, to trigger any operations in the callback function for the advisory.

If the listening correspondent is available (running and reachable), it receives a REGISTRATION.NOT\_CERTIFIED advisory, informing it that the sender no longer certifies delivery of the subject.

25

If the correspondent with this name does not receive certified delivery of the subject from this sender session, then `rvcm_RemoveListener()` returns `RVCM_ERR_BAD_SUBJECT`.

**Parameters**

Parameter	Description
session	A delivery-tracking session.
subject	Cancel certified delivery of this subject.
name	Cancel certified delivery of the subject to the correspondent with this name.

**5 Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL. Or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.  rvcm_RemoveListener() received a NULL listener name or NULL subject; or the sender does not certify delivery of the subject to the listener.



<b>RVCN_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.
<b>RVCN_ERR_BAD_SUBJECT</b>	The function received an ill-formed subject name. Either it is NULL, or contained too many total characters, too many characters in an element, too many elements, or an illegal prefix. rvcn_RemoveListener() received a subject containing wildcard characters; or the sender has not sent certified messages on this subject.
<b>RVCN_ERR_DISALLOWED_LISTENER</b>	rvcn_RemoveListener() cannot cancel certified delivery to this listener because the listener is disallowed.

**Coding Example**

```

cm_err = rvcn_RemoveListener(sess, listener, subject);
5  if(cm_err != RVCN_OK)
    {
        fprintf(stderr, "Can't remove CM listener:\n %s\n",
                rvcn_ErrorText(sess, cm_err));
        exit(-1);
10 }

```

**See Also**

rvcn\_AddListener(), above; and

rvcm\_DisallowListener(), below.

rvcm\_DisallowListener()

5 *Function*

**Declaration**

rvcm\_Error rvcm\_DisallowListener (

rv\_Session session,

10 rv\_Name name )

**Purpose**

15 Cancel certified delivery to all listeners at a specific correspondent. Deny subsequent certified delivery registration requests from those listeners.

**Remarks**

Disallowed listeners still receive subsequent messages from this sender, but delivery is not certified. That is:

20

- The listener receives a REGISTRATION.NOT\_CERTIFIED advisory, informing it that the sender has cancelled certified delivery of all subjects.

25

- If the sender's ledger contains messages sent to the disallowed listener (for which this listener has not confirmed delivery), then the system removes those ledger items, and does not attempt to redeliver those messages.

- The system presents subsequent messages (from the cancelling sender) to the listener with sequence number zero, to indicate that delivery is not certified.

30 Senders can promptly revoke the acceptance of certified delivery by calling rvcm\_DisallowListener() within the callback function that processes the REGISTRATION.REQUEST advisory.

This function disallows a correspondent by name. If the correspondent terminates, and another process instance (with the same reusable name) takes its place, the new process is still disallowed by this sender.

- 5 To supersede the effect of `rvcm_DisallowListener()`, call `rvcm_AllowListener()`.

#### Parameters

Parameter	Description
session	A delivery-tracking session
name	Cancel certified delivery to listeners at the session with this name.

10

#### Errors

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid <code>rv_Session</code> (for example, NULL or a session that has already terminated).
RVCM_ERR_BAD_SESSION_NAME	The function received an ill-formed reusable name.

RVCM_ERR_BAD_ARG	The function received an illegal argument.  rvcm_DisallowListener() received a NULL listener name.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

**Coding Example**

```

cm_err = rvcm_DisallowListener(sess, "LISTENER_17");
5  if(cm_err != RVCM_OK)
    {
        fprintf(stderr, "Can't disallow CM listener: %s\n",
            rvcm_ErrorText(sess, cm_err));
        exit(-1);
10     }

```

**rvcm\_AllowListener()****Function**

15

**Declaration**

```

rvcm_Error rvcm_AllowListener (
    rv_Session      session,
20    rv_Name        name )

```

**Purpose**

Invite the named receiver to reinstate certified delivery for its listeners, superseding the effect of any previous calls to rvcm\_DisallowListener().

25

**Remarks**

Upon receiving the invitation to reinstate certified delivery, the system at the listening program automatically sends new registration requests. The sending program accepts these requests, restoring certified delivery.

5

**Parameters**

Parameter	Description
session	A delivery-tracking session.
name	Accept requests for certified delivery to listeners at the session with this name.

**Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_SESSION_NAME	The function received an ill-formed reusable name.
RVCM_ERR_BAD_ARG	The function received an illegal argument. rvcm-AllowListener() received a NULL listener name.

RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.
------------------------------	--

**Coding Example**

```

cm_err = rvcm-AllowListener(sess, "LISTENER_17");
if(cm_err != RVCM_OK)
5      {
        fprintf(stderr, "Can't allow CM listener:In %sin",
                rvcm_ErrorText(sess, cm_err));
        exit(-1);
      }
10
rvcm_NoAutoConfirm()

```

**Function****15 Declaration**

```

rvcm_NoAutoConfirm(
    rv_Session      session,
    rvcm_ListenId   listenid);

```

**20 Purpose**

Override automatic confirmation of delivery for this listening endpoint.

**Remarks**

The default behavior of certified listeners is to automatically confirm message  
25 delivery upon return from the data callback function (see rvcm\_Callback, above).  
This call selectively overrides this behavior for this specific listening endpoint. (This  
call does not affect other listening endpoints.)

By overriding automatic confirmation, the listener assumes responsibility for  
30 explicitly confirming each inbound certified message by calling rvcm\_Confirm().

Consider overriding automatic confirmation when processing inbound messages involves asynchronous activity, such as computations in other threads, database queries, or additional network communications.

5

No method exists to restore the default behavior, reversing the effect of this function.

#### Parameters

#### Parameter

10

Parameter	Description
session	A delivery-tracking session.
listenId	Override automatic confirmation for inbound certified messages to this listening endpoint.

#### Errors

RVCN_ERR Code	Indicates
RVCN_OK	No error. The call completed successfully.
RVCN_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCN_ERR_NONEXISTENT_LISTENID	rvcm_NoAutoConfirm() received an unusable listenId pointer-either NULL, or it points to something other than an rvcm_ListenId, or it has already been closed.

**See Also**

rvcm\_Callback above, and  
rvcm\_Confirm(), below.

**5 rvcm\_Confirm()****Function****Declaration**

rvcm\_Confirm()

10

```

    rv_Session      session,
    rvcm_ListenId listenerId,
    rv_Name         senderName,
    rvcm_Seq        sequenceNumber)

```

15

**Purpose**

Confirm delivery of a certified message.

**Remarks**

20 Use this function only in programs that override automatic confirmation.

The triplet of subject name, sender and sequence number uniquely identifies each certified message. The subject name is already stored in the listening endpoint. The other two components---sender and sequence number--are explicit parameters of this

25

**Parameters**

Parameter	Description
session	A delivery-tracking session.
listenId	Confirm delivery of a message by this listening endpoint.



senderName	Confirm delivery of a message from the sender with this correspondent name.
sequenceNumber	Confirm delivery of the message with this sequence number.

**Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument. rvcm_Confirm( ) received a sequence number argument that is out of range.
RVCM_ERR_ID_CONFIRM_CONFLICT	rvcm_Confirm() received a listenId that automatically confirms delivery. rvcm_Confirm() is only valid after overriding automatic confirmation with rvcm_NoAutoConfirm().

RVCM_ERR_NONEXISTENT_ID	rvcm_Confirm() received an unusable listenId pointer-either NULL, or it points to something other than an rvcm_ListenId, or it has already been closed.
RVCM_ERR_NONEXISTENT_PUBLISHER	rvcm_confirm() received a senderName argument that is not recognized as the name of a certified sender.

**See Also**

rvcm\_Callback; and rvcm\_NoAutoConfirm(), above.

**5 rvcm\_ReviewLedger()***Function***Declaration**

rvcm\_Error rvcm\_ReviewLedger

10      rv\_Session                      session,  
          rv\_Name                        subject,  
          rvcm\_ReviewCallback        reviewCallbackFn  
          rv\_Opaque                      closureArg );

**15 Purpose**

Summarize the delivery status of messages in the ledger,

**Remarks**

20      The callback function receives one message for each matching subject stored in the ledger. For example, when rvcm\_ReviewLedger() receives FOO. \* as its subject argument, it calls the callback function separately for these matching subjects--once for FOO.BAR, once for FOO.BAZ, and once for FOO.BOX.

However, if the callback function returns non-NULL, then `rvcm_ReviewLedger()` returns immediately.

If the ledger does not contain any matching items, `rvcm_ReviewLedger()` returns normally without calling the callback function.

For information about the content and format of the callback messages, see `rvcm_ReviewCallback`, below.

## 10 Parameters

Parameter	Description
<code>session</code>	A delivery-tracking session.
<code>subject</code>	Review ledger items with this subject.  If this subject contains wildcard characters ("*" or ">"), then review all items with matching subject names. The callback function receives a separate message for each matching subject in the ledger.
<code>reviewCallbackFn</code>	This function receives the review messages.
<code>closureArg</code>	Pass this closure argument to the callback function. This argument must be a pointer, but it can point to any type of data. It contains any information needed by the callback function. the system treats this argument as an opaque closure, forwarding it to the callback function without accessing its value.

## Errors

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_ARG</b>	The function received an illegal argument. rvcm_ReviewLedger() received a NULL subject name or a NULL review callback function.
<b>RVCM_ERR_NO_MEMORY</b>	The function could not complete because the operating system denied its request to allocate storage.
<b>RVCM_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.

**Coding Example**

```
fprintf(stdout, "\nLedger review for subject '%s'. %d:\n",
        subject, reviewMax);
```

5

```
/** See rvcm_ReviewCallback example function, below. */
cm_err = rvcm_ReviewLedger (session, rv_Name)subject,
                           myReviewLedgerCallback,
                           (rv_Opaque)&reviewMax);
```

```
10 if ( cm_err != RVCM_OK)
    {
        fprintf(stderr, "Review ledger failed for '%s':\n\t%s\n",
                subject, rvcm_ErrorText(sess, cm_err));
    }
```

**See Also**

rvcm\_ReviewCallback, above.

**5 rvcm\_ReviewCallback****Datatype****Declaration**

```
void* rvcm_ReviewCallback (  
10     rv_Session      session,  
     rv_Name          subject,  
     rvmsg_Msg        msg,  
     rv_Opaque        closureArg )
```

**15 Purpose**

rvcm\_ReviewCallback is the function type of callback functions for reviewing the ledger. Applications define functions of this type to process the summary messages from rvcm\_ReviewLedger().

**20 Remarks**

rvcm\_ReviewLedger() calls this callback once for each matching subject in the ledger.

To continue reviewing the ledger, return NULL from this callback function. To stop  
25 reviewing the ledger, return non-NULL from this callback function;  
rvcm\_ReviewLedger() returns immediately.

30

**Parameters**

Parameter	Description
session	This parameter receives the current session.
subject	This parameter receives the subject name that the message summarizes.
msg	This parameter receives a summary message describing the delivery status of messages in the ledger. The table below describes the fields of the summary message.
closureArg	This parameter receives a closure argument, which the application supplied when it called <code>rvcm_ReviewLedger()</code> . This argument is a pointer, but it can point to any type of data. It contains any information needed by the callback function. The system treats this argument as an opaque closure, forwarding it to the callback function without accessing its value.

**Message Content**

Field Name	Description
subject	The subject that this message summarizes. This field has datatype <code>RVMSG_STRING</code> .
seqno_last_sent	The sequence number of the most recent message sent with this subject name.  This field has datatype <code>RVMSG_UTNT</code> .

total_msgs	The total number of messages with this subject name. This field has datatype RVMSG_UINT.
total_size	<p>The total storage (in bytes) occupied by all messages with this subject name.</p> <p>If the ledger contains ten messages with this subject name, then this field sums the storage space over all of them.</p> <p>This field has datatype RVMSG_UINT.</p>
listener	<p>Each summary message can contain one or more fields named listener. Each listener field contains a nested submessage with details about a single registered listener.</p> <p>This field has datatype RVMSG_RVMSG.</p>
listener.name	<p>Within each listener submessage, the name field contains the name of the delivery-tracking listener.</p> <p>This field has datatype RVMSG_STRING.</p>
listener.last_confirmed	<p>Within each listener submessage, the last_confirmed field contains the sequence number of the last message for which this listener confirmed delivery.</p> <p>This field has datatype RVMSG_UINT.</p>

**Coding Example**

/\*\* See rvcn\_ReviewLedger() example call, above. \*\*\*/

5 void \*

```

    myReviewLedgerCallback(rv_Session sess,
                           rv_Name subject,
                           rvmsg_Msg msg,
                           rv_Opaque arg)
5   {
    int * count = (int*) arg;
    /* Print the ledger item. */
    printf("\nLedger item for '%s':\n", subject);
    rvmsg_Print(sess, msg, NULL);
10  printf("\n");

    if ( *count )
    {
        (*count)--;
15  if (( *count ) > 0 );
        {
            /* When count reaches zero, stop. Return from rvcm_ReviewLedger() */
            return((void*)sess);
        }
20  }

    return(NULL); /* Otherwise, continue to the next item. */

```

**See Also**

25 *rvcm\_ReviewCallback*

*rvcm\_ReviewLedger()*, above.

*rvcm\_SyncLedgerFile()*

30

**Function****Declaration**

*rvcm\_Error* *rvcm\_SyncLedgerFile* (*rv\_Session* session);



**Purpose**

Synchronize the ledger file to its storage medium.

**5 Remarks**

When this function returns, the session's current state is safely stored in the ledger file.

10 Delivery-tracking sessions that use synchronous ledger files need not call this function, since the current state is automatically written to the file system before returning.

**Parameters**

Parameter	Description
session	Synchronize the ledger file associated with this delivery-tracking session.

15

**Errors**

RVCM Error Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

<b>RVCM_ERR_FILE_IO_ERROR</b>	<b>rvcm_SyncLedgerFile()</b> encountered an error while writing the ledger file.
-------------------------------	--

See Also

**rvcm\_Enable()**, above.

## 5 **rvcm\_Error**

*Datatype*

- 10 **rvcm\_Error** is an enumerated type for error codes. Table A2 lists the possible **rvcm\_Error** values. The user can use the function **rvcm\_ErrorText()** to convert **rvcm\_Error** message codes to descriptive text. For more information, see **rvcm\_ErrorText()** on page 244.

Table A2: Enumerated Values of **rvcm\_Error**

15

<b>RVCM Error Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INIT_FAILURE</b>	<b>rvcm_EnableQueue()</b> could not initialize either the certified delivery or fault tolerance components upon which it depends.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid <b>rv_Session</b> (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_SESSION_NAME</b>	The function received an ill-formed reusable name.

RVCM Error Code	Indicates
	<p>rvcm_ListenSubject() received either a NULL callback function, or a NULL listenid pointer.</p> <p>rvcm_ListenInbox() received either a NULL inbox name pointer, a NULL callback function, or a NULL listenid pointer.</p> <p>rvcm_DisallowListener() received a NULL listener name.</p> <p>rvcm_AllowListener() received a NULL Listener name.</p> <p>rvcm_AdclListener() received a NULL listener name.</p> <p>rvcm_RemoveListener() received a NULL listener name or NULL subject; or the sender does not certify delivery of the subject to the listener.</p> <p>rvcm_Send() or rvcm_SendWithReply() received either a NULL subject, or a NULL sequence number pointer.</p> <p>rvcm_ReviewLedger() received a NULL subject name or a NULL review callback function.</p>

RVCM Error Code	Indicates
	rvcm_Confirm() received a sequence number argument that is out of range.
RVCM_ERR_NO_MEMORY	The function could not complete because the operating system denied its request to allocate storage.
RVCM_ERR_BAD_SUBJECT	<p>rvcm_Send(), rvcm_SendWithReply() or rvcm_ListenSubject() received an ill-formed subject name.</p> <p>Either it is NULL, or contained too many total characters, too many characters in an element, too many elements, a wildcard character, or an illegal prefix.</p> <p>rvcm_RemoveListener() received a subject containing wildcard characters; or the sender has not sent certified messages on this subject.</p>
RVCM_ERR_ID_CONFIRM_CONFLICT	<p>rvcm_Confirm() received a listenid that automatically confirms delivery. rvcm_confirm() is only valid after overriding automatic confirmation with rvcm_NoAutoConfirm().</p>
RVCM_ERR_NONEXISTENT_ID	<p>rvcm_Close(), rvcm_NoAutoConfirm(), or rvcm_Confirm() received an unusable listenid pointer--either NULL, or it points to something</p>

<b>RVCM Error Code</b>	<b>Indicates</b>
	other than an <code>rvcm_ListenId</code> , or it has already been closed.
<b>RVCM_ERR_DUPLICATE_SUBJECT</b>	<code>rvcm_ListenSubject()</code> can open at most one listening endpoint per subject; it cannot open a second listening endpoint for this subject.
<b>RVCM_ERR_NONEXISTENT_PUBLISHER</b>	<code>rvcm_Confirm()</code> received a <code>senderName</code> argument that is not recognized as the name of a certified sender.
<b>RVCM_ERR_DISALLOWED_LISTENER</b>	<p><code>rvcm_AddListener()</code> cannot add this listener because it is disallowed. First call <code>rvcm_AllowListener()</code>.</p> <p><code>rvcm_RemoveListener()</code> cannot cancel certified delivery to this listener because the listener is disallowed.</p>
<b>RVCM_ERR_SESSION_ALREADY_ENABLED</b>	<code>rvcm_Enable()</code> received a session that is already enabled for delivery tracking. It is illegal to enable a session more than once.
<b>RVCM_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.
<b>RVCM_ERR_LEDGER_NAME_CONFLICT</b>	<code>rvcm_Enable()</code> received NULL as the name parameter, but a non-NULL value as the ledgerFile parameter.
<b>RVCM_ERR_PARAMETER_CONFLICT</b>	<p>The function received conflicting values for parameters.</p> <p><code>rvcm_Enable()</code> received <code>RV_FALSE</code> as its <code>requireOldMsgs</code> parameter, and</p>

<b>RVCM Error Code</b>	<b>Indicates</b>
	NULL as its name parameter. A non-reusable name implies a transient correspondent, which cannot have backlog messages.
<b>RVCM_ERR_FILE_IO_ERROR</b>	rvcm_Enable() encountered an error while opening the ledger file. For example, an explicitly named directory does not exist.  rvcm_SyncLedgerFile() encountered an error while writing the ledger file.
<b>RVCM_ERR_FILE_NO_PERMISSION</b>	File access privileges are insufficient for rvcm_Enable ( ) to open the ledger file.
<b>RVCM_ERR_FILE_NOT_LEDGER_OWNER</b>	The reusable name recorded in the file differs from the name of this session. ryere_Enable ( ) stopped reading the file.
<b>RVCM_ERR_CORRUPT_LEDGER_FILE</b>	The ledger file is corrupt. rvcm_Enable() could read only part of the ledger file into process-based memory. Some information may be lost.

**See Also**

rvcm\_ErrorText(), below.

**APPENDIX B: Distributed Queues (Programming Details for C Programmers)**

This Appendix A provides programming details for C programmers wishing to implement Certified message Delivery. The Appendix provides, in Table A1, an overview listing of Certified's messaging Deliver Datatypes and Functions. Each Datatype or Function is then described in greater detail with Cross-references to related Datatypes or Functions.

As described above, Applications can use distributed queues for certified delivery to one of  $n$  listeners (queue member sessions). These distributed queue functions are typically used in combination with certified message delivery.

**Distributed Queue CAPI**

The following Table BA summarizes the datatypes and functions in the distributed queue C API.

Table B1: Distributed Queues: Datatype and Functions

Item	Description	Page
rvcm_EnableQueue()	Enable a session as a distributed queue member	248
rvcm_rvcn_SetQueueAcceptTime() 0	Set the queue time limit for task acceptance.	251
rvcm_QueueAcceptTime()	Return the queue time limit for task acceptance.	253
rvcm_SetQueueCompleteTime()	Set the queue time limit for task completion.	255
rvcm_QueueCompleteTime()	Return the queue time limit for task completion.	257

Item	Description	Page
rvcm_SetQueueListenerWeight()	Set the listener weight of a queue member.	261
rvcm_QueueListenerWeight()	Return the listener weight of a queue member.	261
rvcm_SetQueueListenerTasks()	Set the listener task capacity of a queue member.	263
rvcm_QueueListenerTasks()	Return the listener task capacity of a queue member.	266
rvcm_Error	Datatype. Enumerates error codes for the certified message delivery API and distributed queue API.	239
rvcm_ErrorTest()	Return a text string describing an error code	244

**rvcm\_EnableQueue()***Function***5 Declaration**

```

rvcm_Error rvcm_EnableQueue (
    rv_Session      session
    rv_Name         name,
    unsigned long schedulerWeight,
10    unsigned long schedulerHeartbeat,
    unsigned long schedulerActivation );

```

**Purpose**

Enable a session for certified message delivery as part of distributed queue for one-of-  
15 n certified delivery.

**Remarks**



Each member of a distributed queue listens for the same subjects--yet even when  $n$  members listen, for each inbound message (or task), exactly one member processes the message.

- 5 Programs must call `rvcm_EnableQueue()` before any other calls related to distributed queues or certified listening.

Once a session becomes a queue member, it cannot resign membership except with `rv_Term()`.

10

### Queue Member Roles

Each distributed queue member session has two distinct roles--as a listener, and as a potential scheduler.

- 15 In the **listener role**, queue member sessions support a limited subset of certified delivery calls: `rvcm_ListenSubject()`, `rvcm_NoAutoConfirm()` and `rvcm_Confirm()`. Queue member sessions do not support any other certified delivery calls (in particular, calls associated with sending certified messages). However, they do support all standard system calls (for example, `rv_Send()`).

20

System fault tolerance software maintains exactly one active scheduler in each queue; if the scheduler process terminates, another member assumes the role of scheduler. The queue member session in the **scheduler role** assigns inbound tasks to listeners in the queue. (A scheduler can assign tasks to its own listener component, but only does  
25 so when all other listeners are busy.)

### Parameters

Parameter	Description
session	<p>The call enables this session.</p> <p>Before this call, the session must not yet be enabled for delivery tracking.</p>

Parameter	Description
name	The session becomes part of the distributed queue with this reusable name.
schedulerWeight	<p>Weight represents the ability of this session to fulfill the role of scheduler, relative to other members of the same queue. The queue members use relative scheduler weight values to elect one member as the scheduler; members with higher scheduler weight take precedence.</p> <p>Acceptable values range from 1 to 65535 (even though the parameter is declared as an unsigned long).</p>
schedulerHeartbeat	<p>The scheduler session sends heartbeat messages at this interval (in milliseconds).</p> <p>All sessions in the queue must specify the same value for this parameter. Acceptable values are the unsigned 32-bit integers (except zero).</p>
schedulerActivation	<p>When the heartbeat signal from the scheduler has been silent for this interval (in milliseconds), the queue member with the greatest scheduler weight takes its place as the new scheduler.</p> <p>All sessions in the queue must specify the same value for this parameter. Acceptable values are unsigned 32-bit integers (except zero).</p>

**Errors**

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_SESSION_ALREADY_ENABLED</b>	rvcm_Enable() received a session that is already enabled for delivery tracking. It is illegal to enable a session more than once.
<b>RVCM_ERR_NO_MEMORY</b>	The function could not complete because the operating system denied its request to allocate storage.
<b>RVCM_ERR_INIT_FAILURE</b>	rvcm_EnableQueue() could not initialize either the certified delivery or fault tolerance components upon which it depends.

**See Also**

rvcm\_Enable(), Appendix A

5 rvcm\_ListenSubject(), Appendix A

\*\*\*\*\*

rvcm\_SetQueueAcceptTime()

Function

10 **Declaration**

#define DEFAULT\_ACCEPT\_TIME (0)

rvcm\_Error rvcm\_SetQueueAcceptTime (

rv\_Session session,

15 unsigned long acceptTime );

**Purpose**

Change the accept time parameter of a queue member session.

**5 Remarks**

When this session, acting as the scheduler, assigns a task to a listener (another queue member session), it sets a timer with this length (in milliseconds). If the timer elapses before the scheduler receives acceptance from the listener, the scheduler reassigns the task to another listener.

10

Zero is a special value, which specifies no limit on the acceptance time---that is, the scheduler does not set a timer, and does not reassign tasks.

Enabling a session as a queue member tacitly sets its accept time parameter to

15 **DEFAULT\_ACCEPT\_TIME (zero).****Parameters**

Parameter	Description
session	A session in a distributed queue.
acceptTime	This value (in milliseconds) becomes the new time limit for acceptance of tasks. It must be less than the complete time parameter (unless the complete time is zero).

**20 Errors**

RVCN_ERR Code	Indicates
RVCN_OK	No error. The call completed successfully.

RVCM_ERR Code	Indicates
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENAB LED	The function received a session that is not enabled for delivery tracking.

**See Also**

vcm\_QueueAcceptTime(). below

5

**rvcm\_QueueAcceptTime()***Function*10 **Declaration**

```
#define DEFAULT_ACCEPT_TIME (0)
```

```
rvcm_Error rvcm_QueueAcceptTime (
```

```
15     rv_Session      session,
        unsigned long* acceptTime );
```

**Purpose**

Extract the accept time parameter of a queue member session.

20

**Remarks**

When this session, acting as the scheduler, assigns a task to a listener (another queue member session), it sets a timer for the accept time (in milliseconds). If the timer

elapses before the scheduler receives acceptance from the listener, the scheduler reassigns the task to another listener.

- 5 Zero is a special value, which specifies no limit on the acceptance time (the scheduler does not set a timer).

Enabling a session as a queue member tacitly sets its accept time parameter to DEFAULT\_ACCEPT\_TIME (zero).

## 10 Parameters

Parameter	Description
session	A session in a distributed queue.
acceptTime	This location receives the stored time limit (in milliseconds) for acceptance of tasks.

## Errors

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.

15

rvcm\_Qz,QueueAcceptTime()

RVCM_ERR Code	Indicates
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.

RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.
------------------------------	--

**See Also**

rvcm\_SetQueueAcceptTime(), above

5

rvcm\_SetQueueCompleteTime()

**Function****Declaration**

10 #define DEFAULT\_COMPLETE\_TIME (0)

rvcm\_Error rvcm\_SetQueueCompleteTime (

15       rv\_Session       session,  
      unsigned long completeTime );

**Purpose**

Change the complete time parameter of a queue member session.

**Remarks**

20 When this session, acting as the scheduler, assigns a task to a listener (another queue member session), it sets a timer with this length (in milliseconds). If the timer elapses before the scheduler receives a completion message from the listener, the scheduler reassigns the task to another listener.

25 Zero is a special value, which specifies no limit on the completion time (the scheduler does not set a timer).

Enabling a session as a queue member tacitly sets its complete time parameter to DEFAULT\_COMPLETE\_TIME (zero).

30

**Parameters**

Parameter	Description
session	A session in a distributed queue.
completeTime	This value (in milliseconds) becomes the new time limit for completion of tasks. It must be greater than the accept time parameter (unless the complete time is zero).

**5 Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.

RVCM_ERR Code	Indicates
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.



See Also

rvcm\_QueueCompleteTime(), below

## 5 rvcm\_QueueCompleteTime()

Function

Declaration

```
#define DEFAULT_COMPLETE_TIME (0)
```

10

```
rvcm_Error rvcm_QueueCompleteTime (
    rv_Session      session,
    unsigned long*   completeTime );
```

15

Purpose

Extract the complete time parameter of a queue member session.

Remarks

20 When this session, acting as the scheduler, assigns a task to a listener (another queue member session), it sets a timer for the complete time (in milliseconds). If the timer elapses before the scheduler receives a completion message from the listener, the scheduler reassigns the task to another listener.

25 Zero is a special value, which specifies no limit on the completion time (the scheduler does not set a timer).

Enabling a session as a queue member tacitly sets its complete time parameter to  
DEFAULT\_COMPLETE\_TIME (zero).

30

**Parameters**

Parameter	Description
session	A session in a distributed queue.
completeTime	This location receives the stored time limit (in milliseconds) for completion of tasks.

**5 Errors**

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.

RVCM_ERR Code	Indicates
RVCM_ERR_INVALID_SESSION	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ABG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

**10 See Also**

rvcm\_SetQueueCompleteTime (), below

**rvcm\_Error rvcm\_QueueCompleteTime ()**

**Function**

**5 Declaration**

**#define DEFAULT\_COMPLETE\_TIME (0)**

**rvcm\_Error rvcm\_QueueCompleteTime (**  
                   **rv\_Session                  session,**  
**10      unsigned long\*                  completeTime );**

**Purpose**

Extract the complete time parameter of a queue member session.

**15**

**Remarks**

When this session, acting as the scheduler, assigns a task to a listener (another queue member session), it sets a timer for the complete time (in milliseconds). If the timer  
**20** elapses before the scheduler receives a completion message from the listener, the scheduler reassigns the task to another listener.

Zero is a special value, which specifies no limit on the completion time (the scheduler does not set a timer).

**25**

Enabling a session as a queue member tacitly sets its complete time parameter to **DEFAULT\_COMPLETE\_TIME (zero)**.

**Parameters**

**30**

Parameter	Description
session	A session in a distributed queue.

completeTime	This location receives the stored time limit (in milliseconds) for completion tasks.
--------------	--

## Errors

RVCM_ERR Code	Indicates
RVCM-ERR-INVALID-SESSION	The function received a <i>session</i> argument that is not a valid <i>rv_Session</i> (for example, NULL, or a session that has already terminated).
RVCM-ERR-BAD-ARG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.
RVCM_OK	No error. The call completed successfully.

- 5 See Also  
 rvcm\_SetQueueCompeteTime (), above.

rvcm\_SetQueueListenerWeight()

Function

10

Declaration

```
#define DEFAULT_LISTENER_WEIGHT (1)
```

- 15 rvcm\_Error rvcm\_SetQueueListenerWeight (  
     rv\_Session                      session,

unsigned long listenerWeight );

**Purpose**

Change the listener weight parameter of a queue member session.

5

**Remarks**

When the scheduler receives a task, it assigns the task to the available listener with the greatest listener weight.

10

A listener is considered available unless either of these conditions are true:

- The pending tasks assigned to the listener exceed its task capacity.
- 15 ■ The listener session is the scheduler. (The scheduler assigns tasks to its own listener only when no other listeners are available.)

Enabling a session as a queue member tacitly sets its listener weight parameter to  
20 DEFAULT\_LISTENER\_WEIGHT (1).

**Parameters**

Parameter	Description
session	A session in a distributed queue.
listenerWeight	This value becomes the new listener weight of the session.

**Errors**

5

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a <i>session</i> argument that is not a valid <i>rv_Session</i> (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

**See Also**

*rvcm\_QueueListenerWeight* (), below.

10

*rvcm\_QueueListenerWeight*()

Function

**Declaration**

```
#define DEFAULT_LISTENER_WEIGHT (1)
```

```
5  rvcn_Error rvcn_QueueListenerWeight (
      rv_Session      session,
      unsigned long*   listenerWeight );
```

**Purpose**

10

Extract the listener weight parameter of a queue member session.

**Remarks**

15 When the scheduler receives a task, it assigns the task to the available listener with the greatest listener weight.

A listener is considered available unless either of these conditions are true:

- 20 ■ The pending tasks assigned to the listener exceed its task capacity.
- The listener session is the scheduler. (The scheduler assigns tasks to its own listener only when no other listeners are available.)

25

Enabling a session as a queue member tacitly sets its listener weight parameter to DEFAULT\_LISTENER\_WEIGHT (1).

**Parameters**

30

Parameter	Description
session	A session in a distributed queue.

listenerWeight	This location receives the current listener weight of the session.
----------------	--

### Errors

RVCM_ERR Code	Indicates
RVCM_OK	No error. The call completed successfully.
RVCM_ERR_INVALID_SESSION	The function received a <i>session</i> argument that is not a valid <i>rv_Session</i> (for example, NULL, or a session that has already terminated).
RVCM_ERR_BAD_ARG	The function received an illegal argument.
RVCM_ERR_SESSION_NOT_ENABLED	The function received a session that is not enabled for delivery tracking.

### 5 See Also

`rvcm_SetQueueListenerWeight()`, above.

`rvcm_SetQueueListenerTasks()`

10

*Function*

### Declaration

15

```
#define DEFAULT_LISTENER_TASKS (1)
```



```
rvcm_Error rvcm_SetQueueListenerTasks (  
    rv_Session          session,  
    unsigned long       listenerTasks );
```

5

**Purpose**

Change the listener tasks parameter of a queue member session.

**Remarks**

10

Task capacity is the maximum number of tasks that a listener can accept. When the number of accepted tasks reaches this maximum, the listener cannot accept additional tasks until it completes one or more of them.

15

When the scheduler receives a task, it assigns the task to the listener (a queue member) with the greatest listener weight--unless the pending tasks assigned to that listener exceed its task capacity. When the preferred listener has too many tasks, the scheduler assigns the new inbound task to the listener with the next greatest listener weight.

20

Enabling a session as a queue member tacitly sets its listener tasks parameter to DEFAULT\_LISTENER\_TASKS (1).

Programmers can tune task capacity based on two factors:

25

- Multi-tasking program on multiprocessing hardware.

On a multiprocessing computer, a multi-threaded program that devotes  $n$  threads and  $n$  processors to inbound tasks has task capacity  $n$ .

30

- Communication time lag.

In most distributed queue applications, the communication time is an insignificant fraction of the task turnaround time. That is, the time required to

assign a task and signal its completion is very small compared to the time required to process the task itself. For example, when average task turnaround time is 2000 milliseconds, of which communication time contributes only 10 milliseconds to the total, then task capacity is the same as the number of processors or threads.

However, in some situations communication time can be significant--for example, when the queue members are distributed at distant sites connected by a Wide Area Network (WAN). When communication time is significant, the meaning of task capacity changes; instead of signifying the number of tasks that a listener can process concurrently, it signifies the number of tasks that can fill the listener's capacity despite the communication time lag. For example, when the average task turnaround time is 1500 milliseconds, of which the average task processing time contributes 1000 milliseconds to the total, then setting the task capacity to 3 minimizes the listener's idle time between tasks.

When tuning task capacity to compensate for communication time lag, balance is critical. Underloading a listener (by setting its tasks capacity too low) can cause the listener to remain idle while it waits for the schedule to assign its next task. Conversely, overloading a listener (by setting its task capacity too high) can cause some assigned tasks to wait, while other listeners that might have accepted those tasks remain idle.

## Parameters

Parameter	Description
session	A session in a distributed queue.
listenerTasks	This value becomes the new listener task capacity of the session. The value must be 1 or greater.

**Errors**

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_Session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_ARG</b>	The function received an illegal argument.
<b>RVCM_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.

**5 See Also**

rvcm\_QueueListenerTasks (), below.

**10**

**rvcm\_QueueListenerTasks()**

*Function*

**15 Declaration**

```
#define DEFAULT_LISTENER_WEIGHT (1)
```

```
rvcm_Error rvcm_QueueListenerTasks (
```

```

rv_Session          session,
unsigned long*      listenerTasks );

```

### Purpose

5

Extract the listener tasks parameter of a queue member session.

### Remarks

- 10 Task capacity is the maximum number of tasks that a listener can accept. When the number of accepted tasks reaches this maximum, the listener cannot accept additional tasks until it completes one or more of them.

15 When the scheduler receives a task, it assigns the task to the listener (a queue member) with the greatest listener weight--unless the pending tasks assigned to that listener exceed its task capacity. When the preferred listener has too many tasks, the scheduler assigns the new inbound task to the listener with the next greatest listener weight.

- 20 Enabling a session as a queue member tacitly sets its listener tasks parameter to DEFAULT\_LISTENER\_TASKS (1).

### Parameters

Parameter	Description
session	A session in a distributed queue.
listenerTasks	This location receives the current listener task capacity of the session.

25

### Errors

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_OK</b>	No error. The call completed successfully.

<b>RVCM_ERR Code</b>	<b>Indicates</b>
<b>RVCM_ERR_INVALID_SESSION</b>	The function received a session argument that is not a valid rv_session (for example, NULL, or a session that has already terminated).
<b>RVCM_ERR_BAD_ARG</b>	The function received an illegal argument.
<b>RVCM_ERR_SESSION_NOT_ENABLED</b>	The function received a session that is not enabled for delivery tracking.

See Also

rvcm\_SetQueueListenerTasks(), above.

5

We claim:

1. A method of certified delivery of an outgoing message in a multipoint anonymous, publish/subscribe telecommunications system, said system having at least one publisher and at least one subscriber, said method comprising the steps of:
  - a) establishing a certified delivery session including a certified delivery session name and a certified delivery session ledger;
  - b) labeling the outgoing message with a label including the delivery session name and a sequence number;
  - 10 c) sending the labeled outgoing message; and
  - d) receiving the labeled outgoing message at a subscriber.
2. The method of claim 1 wherein the publisher is unknown to the subscriber, said method further comprising:
  - 15 a) the subscriber requesting registration from the publisher; and
  - b) the publisher thereafter accepting the subscriber's registration request and registering the subscriber.
3. The method of claim 2 further comprising the subscriber requesting registration from the publisher by the method comprising:
  - 20 a) the subscriber adding the publisher's name to a ledger in the subscriber; and
  - b) the subscriber contacting the publisher to request registration.
4. The method of claim 2 further comprising the publisher registering the subscriber by the method comprising:
  - 25 a) the publisher registering the subscriber; and
  - b) the publisher notifying the subscriber of registration.
5. The method of claim 1 further comprising the publisher and subscriber entering into a certified delivery agreement.
  - 30
6. The method of claim 5 further comprising:
  - a) the publisher recording outbound messages, and retaining copies thereof in a ledger until delivered; and

b) the subscriber confirming delivery to the publisher.

7. The method of claim 6 further comprising the subscriber requesting retransmission of messages received out of sequence.

5

8. The method of claim 6 comprising the publisher retaining a copy of the message until the subscribers confirms receipt of the message.

9. The method of claim 1 further comprising:

- 10 a) the publisher sends a message including a sequence number to the subscriber;  
b) the subscriber confirms receipt to the publisher; and  
c) the publisher deletes the message from its ledger.

15 10. The method of claim 9 wherein the publisher is sending a message to a plurality of subscribers, the method further comprising:

- a) the publisher sends a message including a sequence number to a plurality of subscribers;  
b) each subscriber confirms receipt to the publisher; and  
c) the publisher deletes the message from its ledger when all of the subscribers  
20 have confirmed receipt.

11. The method of claim 1 further comprising the subscriber automatically confirming receipt of each labeled message.

25 12. The method of claim 1 further comprising:

- a) the subscriber automatically confirming receipt of each labeled message when the subscriber is processing a synchronous thread or task; and  
b) the subscriber explicitly confirming receipt a labeled message when the subscriber is processing an asynchronous thread or task.

30

13. The method of claim 1 further comprising the publisher requesting confirmation of receipt from a subscriber if confirmation is not received from a subscriber.

14. The method of claim 1 further comprising:

- a) the publisher sequentially numbering each labeled outgoing message;
- b) the subscriber receiving each said message and preserving the sequence in which the messages were received; and
- c) the subscriber only confirming receipt when intervening messages are received.

5

15. The method of claim 1 comprising maintaining persistence during upsets.

16. The method of claim 1 comprising asynchronously managing certified delivery.

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17. The method of claim 1 comprising distributed queuing of messages to one subscriber out of n-subscribers, wherein said n-subscribers constitute a single entity to the publisher, and wherein the individual ones of said n-subscribers indicate their availability to another one of said n-subscribers as a scheduler, and wherein the scheduler only routes messages to those subscribers having weight therefor.

15

18. The method of claim 17 wherein said messages are tasks, said method comprising distributing tasks only to distributed subscribers having weight therefor.

20

19. An article of manufacture comprising computer readable program code for certified delivery of an outgoing message in a multipoint anonymous, publish/subscribe telecommunications system, said system having at least one publisher and at least one subscriber, said article of manufacture comprising:

25

a) computer readable program code for effecting establishing a certified delivery session including a certified delivery session name and a certified delivery session ledger;

b) computer readable program code for effecting labeling the outgoing message with a label including the delivery session name and a sequence number;

c) computer readable program code for effecting sending the labeled outgoing message; and

30

d) computer readable program code for effecting receiving the labeled outgoing message at a subscriber.

20. The program product 19 wherein the publisher is unknown to the subscriber, said program product further comprising:



- a) computer readable program code to effect the subscriber requesting registration from the publisher; and
- b) computer readable program code to effect the publisher thereafter accepting the subscriber's registration request and registering the subscriber.

5

21. The program product of claim 20 further comprising computer readable program code to effect the subscriber requesting registration from the publisher comprising:

- a) computer readable program code to effect the subscriber presenting the labeled  
10 outgoing message to a callback function;
- b) computer readable program code to effect the subscriber adding the publisher's name to a ledger in the subscriber; and
- b) computer readable program code to effect the subscriber contacting the publisher to request registration.

15

22. The program product of claim 20 further comprising computer readable program code to effect the publisher registering the subscriber comprising:

- a) computer readable program code to effect the publisher registering the subscriber; and
- 20 b) computer readable program code to effect the publisher notifying the subscriber of registration.

25

23. The program product of claim 19 further comprising computer readable program code to effect the publisher and subscriber entering into a certified delivery agreement.

24. The program product of claim 23 further comprising:

- a) computer readable program code to effect the publisher recording outbound messages, and retaining copies thereof in a ledger until delivered; and
- 30 b) computer readable program code to effect the subscriber confirming delivery to the publisher.

25. The program product 24 further comprising computer readable program code to effect the subscriber requesting retransmission of messages received out of sequence.

26. The program product of claim 24 further comprising:

a) computer readable program code to effect the publisher sending a message including a sequence number to the subscriber;

5 b) computer readable program code to effect the subscriber confirming receipt to the publisher; and

c) computer readable program code to effect the publisher deleting the message from its ledger.

10 27. The program product of claim 26 further comprising computer readable program code to effect the publisher sending a message to a plurality of subscribers, including:

a) computer readable program code to effect the publisher sending a message including a sequence number to a plurality of subscribers;

15 b) computer readable program code to effect each subscriber confirming receipt to the publisher; and

c) computer readable program code to effect the publisher deleting the message from its ledger when all of the subscribers have confirmed receipt.

20 28. The program product of claim 19 further comprising computer readable program code to effect the subscriber automatically confirming receipt of each labeled message.

29. The program product of claim 19 further comprising:

25 a) computer readable program code to effect the subscriber automatically confirming receipt of each labeled message when the subscriber is processing a synchronous thread or task; and

b) computer readable program code to effect the subscriber explicitly confirming receipt a labeled message when the subscriber is processing an asynchronous thread or  
30 task.

30. The program product of claim 19 further comprising computer readable program code to effect the publisher requesting confirmation of receipt from a subscriber if confirmation is not received from a subscriber.

31. The program product of 19 further comprising:

- a) computer readable program code to effect the publisher sequentially numbering each labeled outgoing message;
- 5 b) computer readable program code to effect the subscriber receiving each said message and preserving the sequence in which the messages were received; and
- c) computer readable program code to effect the subscriber only confirming receipt when intervening messages are received.

10 32. The program product of claim 19 further comprising computer readable program code to effect maintaining persistence during upsets.

33. The program product of claim 19 further comprising computer readable program code to effect asynchronously managing certified delivery.

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34. The program product of claim 19 further comprising computer readable program code to effect distributed queuing of messages.

20 35. The program product of claim 34 further comprising computer readable program code to effect distributing tasks only to distributed subscribers having weight therefor.

25 36. A method of certified delivery of an outgoing message in a multipoint anonymous, publish/subscribe telecommunications system, said system having at least one publisher and at least one subscriber, said at least one subscriber comprising a plurality of n-subscribers, said method comprising the steps of:

- a) establishing a certified delivery session including a certified delivery session name and a certified delivery session ledger;
- b) labeling the outgoing message with a label including the delivery session name and a sequence number;
- 30 c) sending the labeled outgoing message;
- d) receiving the labeled outgoing message at an individual one of said n-subscribers, wherein said individual one of said n-subscribers is selected by one of said n-subscribers as a scheduler to receive the message.

37. The method of claim 36 wherein said n-subscribers constitute a single entity to the publisher, and further comprising:
- a) individual ones of said n-subscribers indicate their weight to receive messages;
  - 5 b) the scheduler routing sending messages to those subscribers having weight therefor.
38. The method of claim 36 wherein
- a) one of said n-subscribers is a scheduler,
  - 10 b) individual ones of said n-subscribers send messages to the scheduler indicating their individual weight to receive messages, and
  - c) said scheduler directs the message to the particular one of said n-subscribers with the greatest weight therefor.
- 15 39. The method of claim 38 wherein only one of the n-subscribers processes the message.
40. The method of claim 39 wherein the one of the n-subscribers processing the message can listen to the message, override confirmation of delivery, or confirm
- 20 delivery of the message.
41. The method of claim 39 wherein only one of said n-subscribers is a scheduler at any one time.
- 25 42. The method of claim 41 comprising assigning scheduler responsibility to the one of n-subscribers having the greatest scheduler weight.
43. The method of claim 38 comprising assigning the message to the one of n-subscribers having the greatest listener weight.
- 30 44. The method of claim 38 wherein said individual n-subscribers share a reusable correspondent name.

45. The method of claim 36 wherein said messages are tasks, and said method comprises distributing tasks only to distributed subscribers having weight therefor.

5 46. An article of manufacture comprising computer readable program code for certified delivery of an outgoing message in a multipoint anonymous, publish/subscribe telecommunications system, said system having at least one publisher and at least one subscriber, said at least one subscriber comprising a plurality of n-subscribers, said article of manufacture comprising:

- 10 a) computer readable program code for effecting establishing a certified delivery session including a certified delivery session name and a certified delivery session ledger;
- b) computer readable program code for effecting labeling the outgoing message with a label including the delivery session name and a sequence number;
- c) computer readable program code for effecting sending the labeled outgoing
- 15 message,
- d) computer readable program code for effecting selection of an individual one of said n-subscribers to receive said message by another one of said n-subscribers, and
- e) computer readable program code for effecting receiving the labeled outgoing message at the individual one of said n-subscribers so selected,

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47. The program product of claim 46 wherein said n-subscribers constitute a single entity to the publisher, and further comprising:

- a) computer readable program code for effecting individual ones of said n-subscribers to indicate their weight to receive messages; and
- 25 b) computer readable program code to effect a scheduler routing messages to those subscribers having weight therefor.

48. The program product of claim 46 wherein

- a) one of said n-subscribers is a scheduler,
- 30 b) individual ones of said n-subscribers send messages to the scheduler indicating their individual weight to receive messages, and
- c) said computer readable program code further includes program code to effect said scheduler directing the message to the particular one of said n-subscribers with the greatest weight therefor.

49. The program product of claim 48 wherein only one of the n-subscribers processes the message.

5 50. The program product of claim 49 further comprising computer readable program code to effect the one of the n-subscribers processing the message to:

- a) listen to the message,
- b) override confirmation of delivery, or
- c) confirm delivery of the message.

10

51. The program product of claim 49 wherein only one of said n-subscribers is a scheduler at any one time.

15 52. The program product of claim 51 further comprising computer readable program code to effect assigning scheduler responsibility to the one of n-subscribers having the greatest scheduler weight.

53. The program product of claim 48 comprising computer readable program code to assign the message to the one of n-subscribers having the greatest listener weight.

20 54. The program product of claim 48 wherein said individual n-subscribers share a reusable correspondent name.

55. The program product of claim 46 wherein said messages are tasks, and said program product further comprises computer readable program code to effect  
25 distributing tasks only to distributed subscribers having weight therefor.

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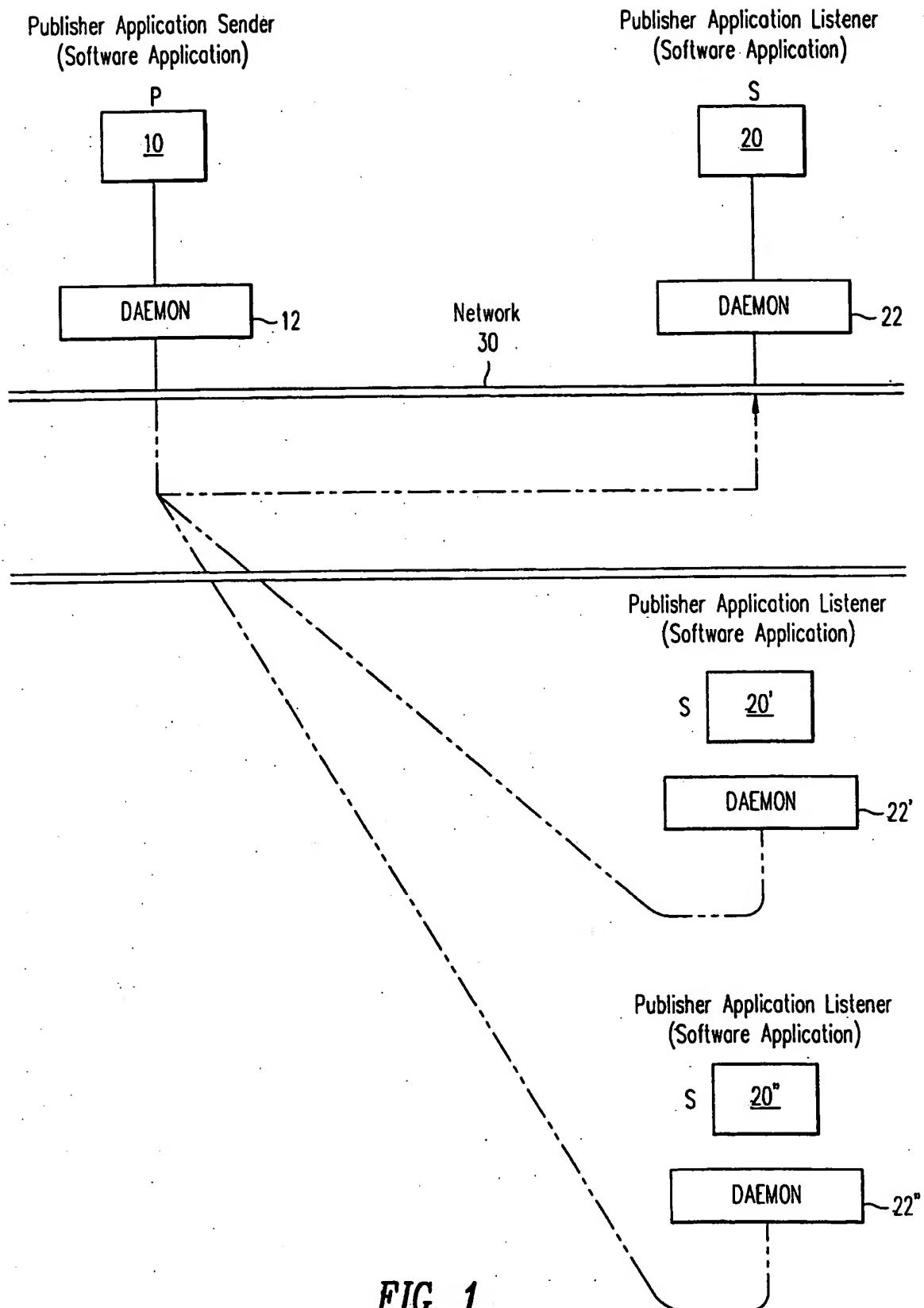
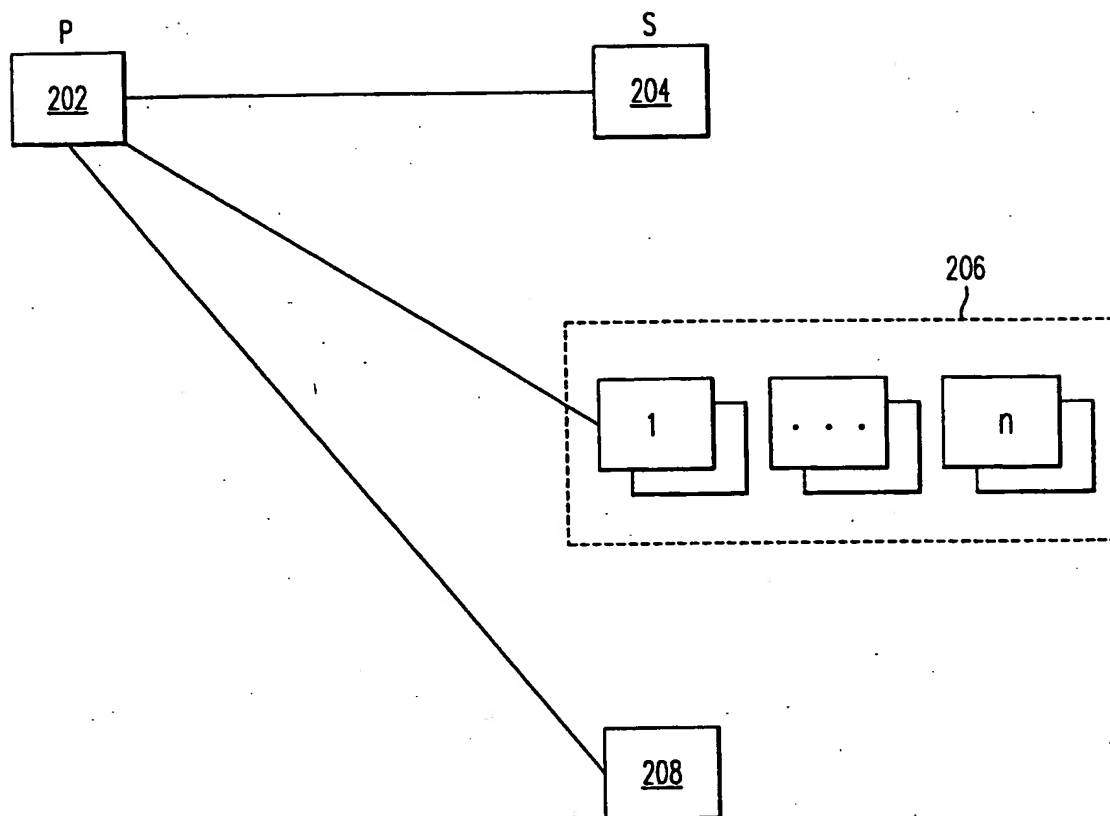


FIG. 1

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**FIG. 2**



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/17115

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 15/16

US CL :395/200.67

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/200.67, 200.82, 200.73; 370/390

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,557,798 A (SKEEN et al.) 17 September 1996, see especially the figures.	1-14, 16, 19-31
A	US 4,356,550 A (KATZMAN et al.) 26 October 1982, see abstract, figures.	15, 32
A	US 5,555,404 A (TURBJORNSSEN et al.) 10 September 1996, See figures, abstract.	17,18,34-55
A	US 5,680,551 A (MARTINO, II) 21 October 1997	1
A	US 5,003,473 A (RICHARDS) 26 March 1991	1
A	US 5,136,501 A (SILVERMAN et al.) 04 August 1992	1

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

17 NOVEMBER 1998

Date of mailing of the international search report

11 JAN 1999

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